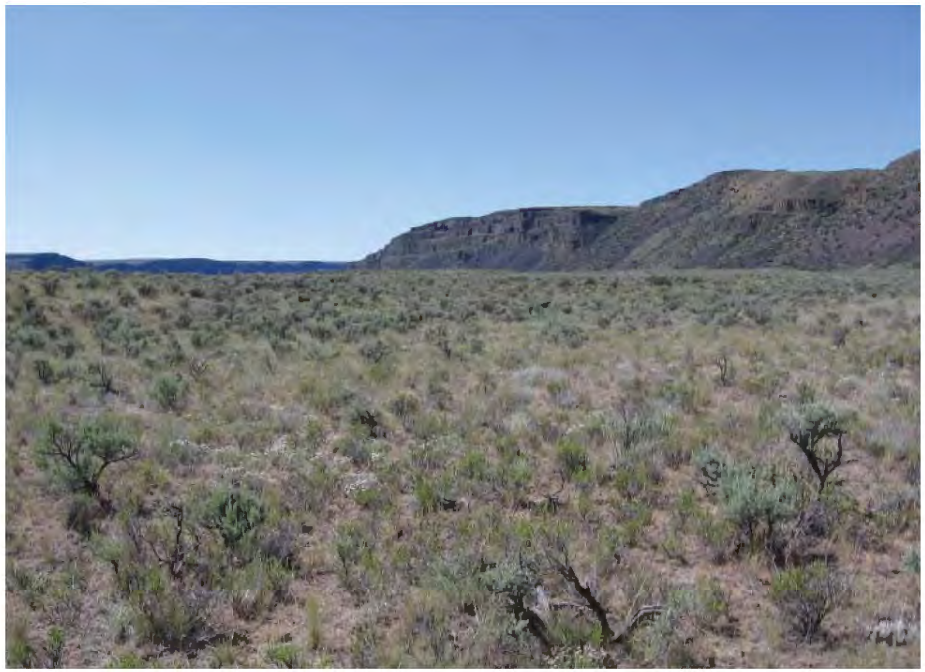
Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin



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Technical Note 430

University of Idaho
College of Natural Resources

Joint Fire Science Program

Sagebrush Steppe
SageSTEP
Treatment Evaluation Project

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Stebleton, A. and S. Bunting. 2009. Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 430. Bureau of Land Management, Denver, CO, BLM/ID/PT-09/002+2824. 81p.

BLM/ID/PT-09/002+2824

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Abstract

Prescribed fire is increasingly used for fuels management and ecosystem restoration. Managers and fuels specialists of the Great Basin are often required to estimate fuel loadings to predict fire behavior, recommend fuel treatments, or restore an area to its natural fire regime. Because of invasive species and woodland encroachment, there have been extensive changes in the fire regimes of sagebrush steppe over the past 150 years. After two years of pre-treatment sampling across six states of the Great Basin, the Sagebrush Steppe Treatment and Evaluation Project (SageSTEP) measured many variables including vegetation, soils, hydrology, wildlife, and fuels. These data will be instrumental in assessing the effectiveness of prescribe burning, chemical and mechanical treatments and provide a better estimate of the vegetation and fuels that currently exist on the sites. The 'Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin' assimilates the SageSTEP pretreatment vegetation and fuels data into an assessment tool that will help users better estimate percent cover, stem density and fuel loadings for their site. Designed similarly to the Natural Fuels Photo Series, produced by USDA Forest Service Fire and Environmental Research Applications team (FERA), this Guide provides the necessary landscape-level inputs required by fire behavior and fire effects models along with building custom fuelbeds. Through the use of photographs and tables with the range of values for each vegetation type, a user should be able to quickly appraise their site by fuel stratum.

Acknowledgements

We recognize Chad Hoffman, University of Idaho, Dr. Karen Launchbaugh, University of Idaho, and Dr. Susan Prichard, University of Washington, for their expertise and input on this Guide; the SageSTEP field crews lead by Jeff Burnham, Brad Jessop, Travis Miller, Jamie Ratchford, and Scott Shaff for all the data collection and pictures; Courtney Loomis for his work on variable derivations; Dr. Chris Williams, University of Idaho, for his statistical counsel; Dr. Roger Ottmar, USDA Forest Service, and the FERA team for their expertise; Summer Olsen for layout and design; the SageSTEP team and principle investigators for their guidance and support; Annie Brown, BLM Salt Lake City Field Office, Brook Chadwick, BLM Salt Lake City Field Office, Beth Corbin, Wasatch-Cache and Uinta National Forest, Louisa Evers, Oregon BLM, Albert Flores, Gila National Forest, Sandy Gregory, Nevada Office of Fire and Aviation, Donald Tschida, Prineville BLM, Rivers Division, and Donovan Walker, Battle Mountain District for their review and suggestions.

This is contribution number 04 of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), supported by funds from the U.S. Joint Fire Science Program. This is contribution number 1036 of the Idaho Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow. Printing and distribution of this guide was funded by the Bureau of Land Management Idaho State Office.

Introduction

SageSTEP (Sagebrush Steppe Treatment Evaluation Project) is an interdisciplinary, five-year study to evaluate the effects of various restoration treatments in sagebrush steppe communities of the Great Basin (McIver et al. 2005). Sagebrush steppe, characterized by dry, open expanses dominated by sagebrush plant communities, is one of the most threatened vegetation types in North America (Noss et al. 1995). Loss of sagebrush steppe is often attributed to shifting fire regimes as a result of non-native grass invasion, especially cheatgrass (*Bromus tectorum*), and pinyon pine (*Pinus edulis* and *Pinus monophylla*) and juniper (*Juniperus spp.*) encroachment (Pellant 1994, Miller and Tausch 2001). SageSTEP is funded by the Joint Fire Science Program and involves collaboration with five universities, six federal agencies, and one non-profit organization. The overall goal of SageSTEP is to identify abotic and biotic thresholds that influence the sustainability of sagebrush steppe communities and provide information to managers, ranchers, and the general public to help restore sagebrush steppe to a healthier, more diverse ecosystem.

Cheatgrass has invaded nearly 25 million acres of the Great Basin (Olson 2008). Cheatgrass is able to gain a foothold in native communities by providing a continuous bed of fine fuel susceptible to fire at a time when it is most harmful to native perennials (Peters and Bunting 1994) because of its ability to germinate and establish before native perennial grasses (Bradford and Lauenroth 2006) and because it cures earlier in the growing season than perennials (Mutch 1967).

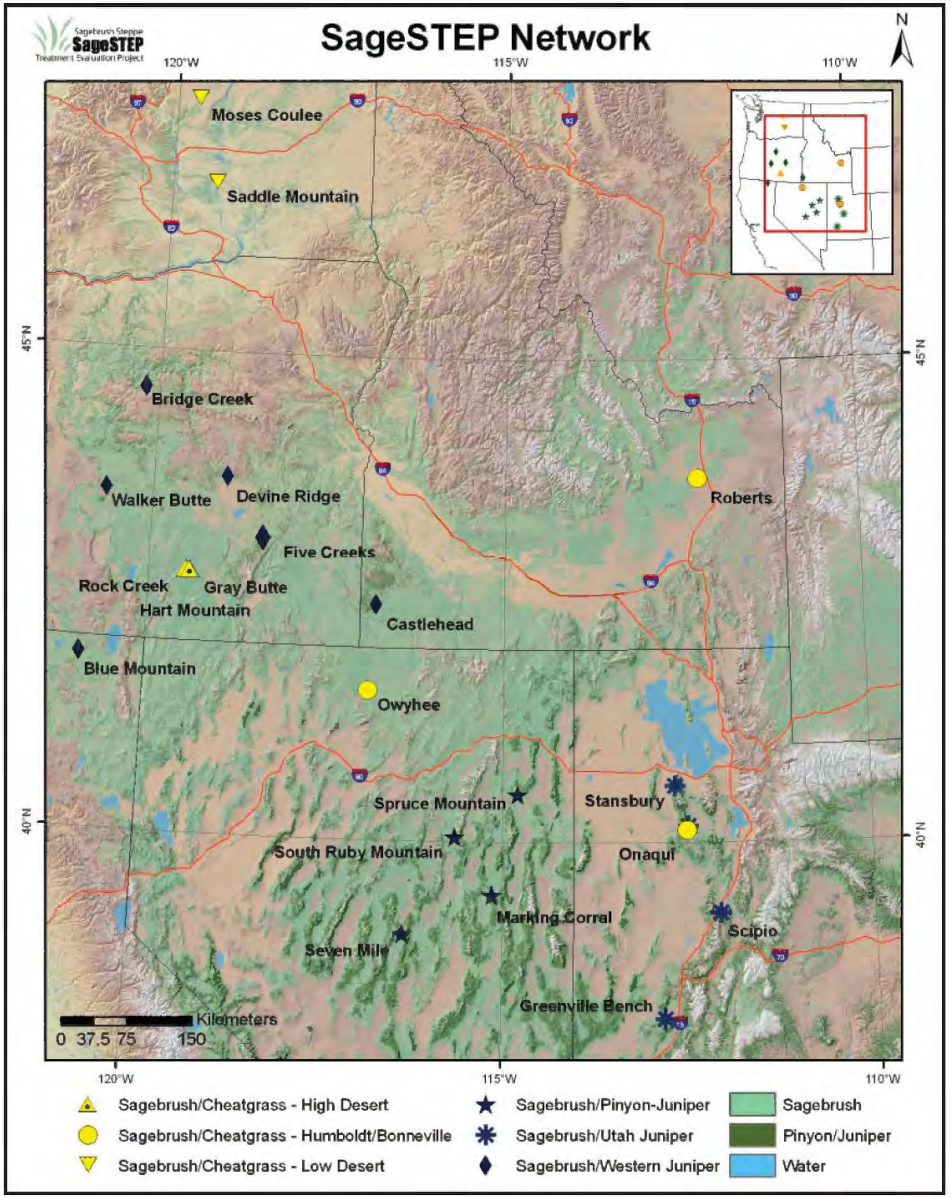


Figure 1. SageSTEP Site Map; for reference with site names. Site specific information is available at http://www.sagestep.org/locations.html.

Cheatgrass dominance has shifted the mean fire return interval from 50–100+ years, in healthy Wyoming big sagebrush dominated communities, to less than 10 years (Whisenant 1990). Increased fire frequency perpetuates cheatgrass expansion, quickly depletes the sagebrush seed bank, and converts native vegetation to an annual grassland (Whisenant 1990). This is the concern in the Sagebrush/Cheatgrass locations (Figure 1). These will be referred to as the 'sagebrush sites' for the rest of the Guide.

Woodland encroachment of pinyon pine and juniper has caused a major shift in species assemblages and altered fire regime of sagebrush steppe landscapes (McIver et al. 2005). The average fire return interval has shifted from 10–50 years, in healthy Mountain big sagebrush dominated communities, to more than 50 years (Miller et al. 1999, Miller and Tausch 2001). When fire does burn in these woodlands it is characterized by extreme fire behavior and results in more stand replacing fire than in historic sagebrush communities. Native species recover slowly following high intensity fires, allowing further invasion of exotics over large areas. This is the major concern in the Sagebrush/Pinyon-Juniper, Sagebrush/Utah Juniper, and Sagebrush/Western Juniper locations (Figure 1). These will be referred to as the 'woodland sites' for the rest of the Guide.

The 'Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin' was created using pretreatment data collected by five field crews in 2006 and 2007. The SageSTEP network consists of five regional networks with 21 total sites spanning Washington, Oregon, California, Idaho, Nevada and Utah (Figure 1). Each site was a replicated, stand-alone experiment, however because there was a common sampling design, data were aggregated for regional representation.

Why is the Guide needed?

The Fuels Guide is the only SageSTEP publication summarizing the pretreatment vegetation and fuels data across 18 sites and all 5 regions into a usable tool for managers and other land stewards. Modeled after the Natural Fuels Photo Series (Ottmar et al. 2000), it allows users to quickly access percent cover, stem density and fuel loadings by fuel stratum (Ottmar et al. 2007). This information is often time-consuming and expensive to collect on a field site. The Fuels Guide increases the efficiency by giving users pictures coupled with data to make predictions based on ocular estimates and/or limited field sampling. Fuels information gathered from this Guide may be used as inputs for fire behavior and effects modeling, creating custom fuelbeds, and for a range of other applications, including describing baseline and/or target conditions for restoration projects.

Methods

SageSTEP employed a randomized design that was implemented across all 18 sites used to create this Guide, including 1530 subplots, within the Great Basin (Figure 1). At each site, subplots were established along a systematic grid with a minimum distance of 164 ft (50 m) between the center of each subplot. Sagebrush sites were at least 200 acres (80.9 ha) with 160 subplots; woodland sites ranged from 25–50 acres (10.1–20.2 ha) with 60 subplots. Each subplot was 98.4 x 108.3 ft (30 x 33 m) with 5 vegetation transects and 1 fuels transect (Figure 2). Two fuels transects are represented in Figure 2 accounting for the two different years of sampling. Transects ran parallel to the 108.3 ft (33 m) length allowing a 4.9 ft (1.5 m) buffer on either end.

A common measurement protocol was used across all sites. Refer to Table 1 for specific methods and transects used for each reported variable by fuel stratum (Ottmar et al. 2007). Descriptive variables for all subplots included: region name, site name, treatment, subplot number, sampling year, UTM coordinates at zero corner, percent slope, aspect, macro-topography (ridgetop, sideslope, terrace, or bottom), and micro-topography (flat, convex, or concave).

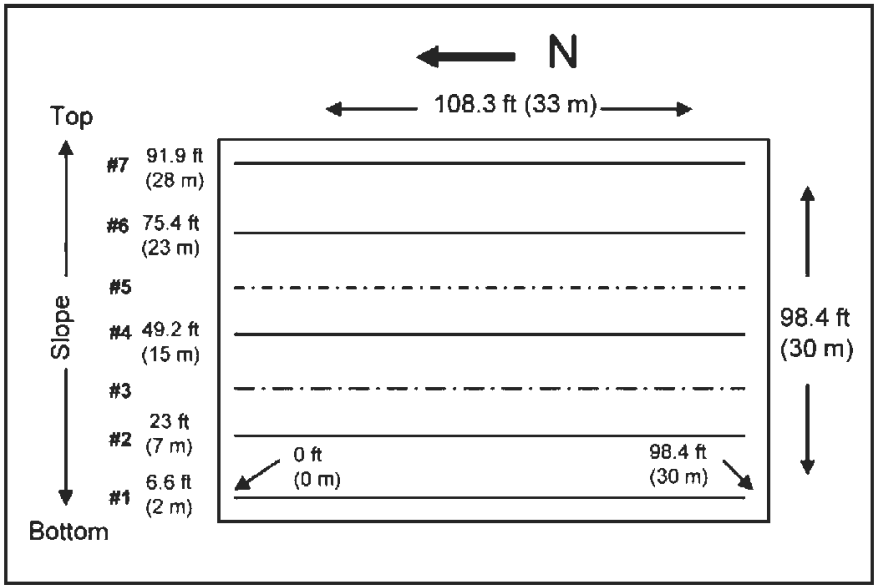


Figure 2. Subplot and transect layout. Solid lines signify vegetation transects; dotted lines denote fuels transects.

Prior to sampling, the Sagebrush/Cheatgrass site managers assigned phases to the subplots in the sagebrush sites based on an ocular estimate of understory grass dominance. Phase 1 was dominated by perennial grasses with very little if any annual grass (primarily cheatgrass) present. In Phase 2 there was a co-dominance between annual and perennial grasses. Phase 3 was an annual grass dominated understory. After sampling was completed for 2006 and 2007, an ANOVA, using SAS9.1, was used to test the significance between the phases based on the canopy cover of perennial and annual grasses. There was no significant difference (α=0.05) between phases. Another ANOVA was run to test significance between all sagebrush sites based on species composition and loading. Again, no significant difference (α=0.05) was found between any of the sites. All seven sites were combined into one sub-guide, Sagebrush Steppe Fuels Guide. It was separated into four groups categorized by less than or greater than 25 percent sagebrush cover and less than or greater than 25 percent total grass cover. This allows the user to more efficiently assign their field site to a group based on an ocular cover estimate.

Table 1. Sampling methods used for each of the reported variables by fuel stratum (Ottmar et al. 2007). Refer to Figure 2 for transect number reference.

Stratum	Variable(s)	Method	Transect(s)#
Trees	Density <1.6 ft (0.5 m) tall	Belt transect (Krebs 1999; Salzer 1994)	2, 4, 6
	All others	Census	NA
Shrubs	Cover	Line point intercept (Bonham 1989)	1, 2, 4, 6, 7
	Height	Nested circular frame (Bonham 1989)	4
	Density	Belt transect (Krebs 1989; Salzer 1994)	2, 4, 6
		Nested circular frame (Bonham 1989)	4
	Loading and Bulk density	Harvest (Pechanec and Pickford 1937; Riser 1984)	NA
		Nested circular frame (Bonham 1989)	4
Nonwoody Fuels	Cover	Line point intercept (Bonham 1989)	1, 2, 4, 6, 7
	Height	19.7 in. X 19.7 in. (50 cm X 50 cm) quadrat (Bonham 1989)	3 in 2006; 5 in 2007
	Loading and Bulk density	Harvest (Pechanec and Pickford 1937; Riser 1984)	3 in 2006; 5 in 2007
		19.7 in. X 19.7 in. (50 cm X 50 cm) quadrat (Bonham 1989)	3 in 2006; 5 in 2007
Woody Fuels	10-hour loading	Planar intercept (Brown et al. 1982)	2, 4, 6
	100-hour loading	Planar intercept (Brown et al. 1982)	2, 4, 6
	1000-hour Sound and Rotten loading	Planar intercept (Brown et al. 1982)	1, 2, 4, 6, 7
Litter and Duff	Cover	Line point intercept (Bonham 1989)	1, 2, 4, 6, 7
	Interspace loading and Bulk density	Harvest (Pechanec and Pickford 1937; Riser 1984)	3 in 2006; 5 in 2007
		19.7 in. X 19.7 in. (50 cm X 50 cm) quadrat (Bonham 1989)	3 in 2006; 5 in 2007
	Tree litter and duff depth, Loading, and Bulk density	Harvest (Pechanec and Pickford 1937; Riser 1984)	NA
		9.8 in. X 9.8 in. (25 cm X 25 cm) quadrat (Bonham 1989)	NA

The methods were the same for the woodland sites. Site managers assigned phases to each subplot based on juniper and/or pinyon pine cover. The phases were identified by Miller et al. (2005): Phase 1, the trees may be present on the site however the shrub and herbaceous layers are the dominant influence on ecological processes (hydrologic, nutrient, and energy cycles), Phase 2, the trees are co-dominant with the shrub and herbaceous layers, and Phase 3, the trees are the dominant vegetation as well as the primary layer influencing ecological processes. There was a significant difference (α=0.05) between tree and shrub cover as well as tree and herbaceous cover between the three phases as determined by an ANOVA and Tukey's studentized range statistic in SAS9.1. The three woodland sites were also significantly different (α=0.05) based on species composition and loading using the same statistical method. Three different sub-guides, Pinyon-Juniper Fuels Guide, Utah Juniper Fuels Guide, and Western Juniper Fuels Guide, were developed to capture the diversity between different woodlands.

All reported measurements were converted to English units to allow for quick input into computer fire behavior and fire effects models as well as account for manager preference. A conversion table is provided in Appendix III. Minimum, maximum and mean values are reported to allow the user to better assess their site within the range represented by a particular group or phase. Only common species are reported in this Guide. All species codes, common names and scientific names are in agreement with the USDA Plants Database (USDA NRS 2008) and are reported in Appendix I.

Trees

Total tree canopy cover for each subplot was calculated based on the area of the longest and perpendicular diameters relative to the total ground surface area of the sample. All trees rooted in the subplot greater than 1.6 ft (0.5 m) tall were measured. Each tree was identified by species and recorded as dead or alive. Trees less than 1.6 ft (0.5 m) tall were counted within a 3.3-ft (1-m) belt on either side of 3 transects giving sapling density (Table 1). Tree density for trees taller than 1.6 ft (0.5 m) tall were tallied throughout the whole subplot. All dead trees were tallied. Height to live crown was defined as the height to the lowest live branch (Reinhardt et al. 2006). Height, height to live crown, longest and perpendicular crown diameters were recorded to the nearest 3.9 in. (10 cm); diameter at breast height (DBH) and basal diameter were not measured. Tree canopies were measured separately even if they intermingled with other canopies. If a tree canopy was completely surrounded by a dominant tree's canopy or individual stems were within 3.3 ft (1 m) of the dominant tree, they were considered one tree.

Live and dead canopy loadings were calculated using allometric equations developed by Sabin (2008) and Tausch (2008). Reported available loading assumes 100% of foliage and 50% of the 1-hour fuels are available to burn at any given time (Scott and Reinhart 2001). Since this assumption may not accurately represent pinyon or juniper species, refer to Appendix IV for tree loadings by size class to calculate a more appropriate value for available fuel. Canopy bulk density is calculated as the total loading divided by the crown height to give a weight per unit volume.

Shrubs

Total shrub canopy cover for each subplot was derived from 300 intercept points per subplot (60 points over 5 transects) using the line point intercept method (Bonham 1989; Table 1). For common shrub species, densities were derived from counts within a 3.3-ft (1-m) belt on either side of 3 transects (Table 1). Densities for rare shrubs were derived from counts within the 3.3-, 6.6-, or 9.8-ft (1-, 2-, or 3-m) radius nested circular frames used to measure shrub volumes (Table 1). The most abundant shrub species and height class, 2–6 in. (5–15 cm) tall or greater than 6 in. (15 cm) tall, were tallied; rare shrubs that landed within the belt were recorded by not separated by height class. Dead shrubs were tallied.

All shrub species greater than 6 in. (15 cm) tall were measured at 5 sample points along transect 4 (Table 1). Height, longest diameter and perpendicular diameter were recorded within either 3.3-, 6.6-, or 9.8-ft (1-, 2-, or 3-m) radius nested circular frames. Size of the nested plot was chosen based on the minimum requirement to measure at least 15 of each common shrub species per subplot. Shrubs must have been rooted within the nested plot to be counted. Shrubs with less than 10% live canopy cover were not recorded. A range of sizes of dominant shrub species, as identified by the site managers, were destructively sampled and separated into the different fuel classes (1-hour [includes foliage], 10-hour and 100-hour). Samples were oven-dried at 58°F for 48 hours. Total shrub loading was calculated as the difference between the wet field weight and dry weight (Pechanec and Pickford 1937). Statistical regressions were developed from the destructively sampled shrubs to predict shrub loadings using height, longest diameter, perpendicular diameter and volume as covariates (Rittenhouse and Senva 1977). These regressions were developed using PROC REG and PROC PRESS in SAS9.1 and were site and species specific. Reported R^2 values in Appendix VI are the lowest R^2 obtained across the different size classes. Available loading, used to calculate shrub bulk density, assumed all foliage and 1-hour fuels consumed while only 50% of the 10-hour fuels consumed (Wright 2008). Shrub loadings by size class and available loadings are reported in Appendix V.

Nonwoody Fuels

Total perennial and annual grass and forb canopy cover for each subplot were derived from 300 intercept points per subplot (60 points over 5 transects) using the line point intercept method (Bonham 1989; Table 1). Total loadings were derived through destructive sampling along the fuels transect. All herbaceous vegetation, standing litter, and surface litter were collected from a 19.7 x 19.7 in. (50 x 50 cm) quadrat (Bonham 1989) with 15 sample points in the woodland sites and 8 sample points in the sagebrush sites. Heights of the tallest grass and forb were measured before clipping. All vegetation was removed within 2.5 in. (1 cm) of the ground and sorted as live herbaceous, standing dead herbaceous and litter. Samples were oven-dried at 58°F for 48 hours. Total herbaceous loading was calculated as the difference between the wet field weight and dry weight (Pechanec and Pickford 1937). Bulk density was calculated using the total loading, assuming the available fuel is 100%, and taking the landscape average of all grass and forb heights.

Woody Fuels

A modification of the planar intercept method (Brown et al. 1982) was used to sample dead, down woody fuels within subplots. Ten- and 100-hour fuels were tallied below 6.6 ft (2 m) along 3 transects (297 ft (90 m) total) per subplot (Table 1). A diameter for each 1000-hour fuel was measured at the point of intersection along 5 transects, 492.1 ft (150 m), per subplot and a decay class of sound or rotten was assigned to each (Table 1). One-hour fuels were not tallied. Brown's (1974) equations were used to assign loadings, by size class, for each subplot.

Litter and Duff

Interspace litter was collected from 19.7 x 19.7 in. (50 x 50 cm) quadrats (Bonham 1989) sampled at 15 sample points in the woodland sites and at 8 sample points in the sagebrush sites. Litter was collected following the clipping of all herbaceous vegetation within the 19.7 x 19.7 in. (50 x 50 cm) quadrat (Bonham 1989). Samples were oven-dried at 58°F for 48 hours. Total interspace litter loading was calculated as the difference between the wet field weight and dry weight (Pechanec and Pickford 1937).

Tree litter and duff samples were collected from 6 trees greater than 6.6 ft (2 m) in crown diameter rooted within the subplot, 2 closest to the center and 1 closest to each of the 4 corners. A 9.8 x 9.8 in. (25 x 25 cm) quadrat (Bonham 1989) was used to sample at the base of the tree, 1/3 of the canopy from the base for trees 6.6–13.1 ft (2–4 m) in crown diameter, and 2/3 of the canopy from the base for trees greater than 13.1 ft (4 m) in crown diameter. The litter and duff was separated and weighed in the field. Samples were oven-dried at 58°F for 48 hours. Total loading was calculated as the difference between the wet field weight and dry weight (Pechanec and Pickford 1937). Litter and duff depths were measured from the remaining profile within the quadrat once all material was removed. The difference in the wet and dry weights combined with and depths were used to calculate the litter and duff bulk density assuming all fuel was available.

Bare ground percent cover was derived from hits along 300 intercept points per subplot (60 points over 5 transects) using the line point intercept method (Bonham 1989; Table 1). This is the only measure of fuel continuity.

Using the Great Basin Fuels Guide

The ‘Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin’ will help users quickly and inexpensively estimate the fuel loadings on their site. Designed similarly to the Natural Fuels Photo Series, produced by the USDA Forest Service Fire and Environmental Research Applications team (FERA), this Guide provides the necessary landscape-level inputs required by existing fire behavior models. Through the use of photographs and tables, with the range of values, users can quickly appraise fuels by the various fuel strata. Because of the high variability of fuel distribution across individual sites, it is generally necessary to use more than one site from the Fuels Guide to represent each particular fuel strata of a field site.

The Fuels Guide is divided into four sub-guides (one sagebrush and three woodland guides) based on regional differences in site physiognomy and ecology: Sagebrush Steppe, Pinyon-Juniper, Utah Juniper, and Western Juniper. Sections are aggregated by sagebrush and total grass cover in the Sagebrush Steppe Guide and by phases (Miller et al. 2005) in the woodland Guides (Refer to Methods section for further explanation). Four photos depict the range of canopy cover by life-form within the group or phase. Photos are arranged by increasing cover of the dominant overstory vegetation.

The user notes and information box below photographs give more background on specific sites sampled. Refer to Figure 1 for site names and locations. Number of subplots reported is the number of sampling units for that particular group or phase. Elevation range includes the range of all sites sampled within that group or phase. Society of Range Management (SRM) and Society of American Foresters (SAF) cover type(s) delineate a descriptive classification of forest and rangelands based on present occupancy of an area by dominant species (Shiflet 1994; Eyre 1980). The fuel model designation(s) only reference the new 40 fuel models (Scott and Burgan 2005). They were assigned based on the total loadings by size class for the group and phases. The original 13 fuel models (Anderson 1982) are not reported because they do not represent the fuels on these sites. Due to the range of shrub and herbaceous loadings within group or phase there is often more than one possible fuel model listed for a group or phase. To assign the correct model, users must pay careful attention to the specific shrub and herbaceous loadings at their field site and assign the correct model based on the different loadings’ influence on fire intensity and/or rate of spread.

Five steps for effective use:

1. Assess each fuel stratum individually (trees, shrubs, nonwoody fuel, woody fuel, and litter).
2. Compare the field site to the Fuels Guide group(s) or phase(s) that most closely resembles field observations. Multiple groups or phases may need to be used to capture the variability of the field site.
3. Decide where within the range of values the fuel strata of the field site fits and/or interpolate between groups or phases.
4. Some strata are not possible to estimate using photos (little and duff depths). A combination of field sampling and observations with this Guide should be incorporated for the most accurate results.
5. Repeat these steps for each fuel stratum of interest obtaining the necessary inputs.

Author Recommendations for Guide Use

For the user to most effectively use this Guide, we recommend accounting for the assumptions and limitations listed below.

- Sampling on all sites took place from April to August (See Guide Notes in the sub-guides for more specifics). No distinction for seasonality was made in the reported variables. When comparing your field site to the photographs and reported values, be sure to account for the difference in seasonality. This is especially critical in regards to the loadings of live and dead herbaceous fuels.
- Minimum and maximum values are included to capture the range of variability within groups or phases. However, in most cases, data are not normally distributed and reported means are much closer to minimum than maximum values.
- It is difficult to distinguish woody fuels and litter and duff fuel strata in the photographs. Independent sampling or observations may be required to gain the most accurate values for these strata.
- One-hour fuels and tree diameters were not collected. If this is required information, the user should make these measurements on their field site.
- Fuel bed depth, a critical input in existing fire behavior models, was not measured. It is NOT recommended to assume this value using the heights reported in the Guide. This should be measured on the site due to the sensitivity of the Rothermel surface fire spread model (Rothermel 1972) to this input.

Further Information

- Joint Fire Science: http://www.firescience.gov
- Sagebrush Steppe Treatment and Evaluation Project (SageSTEP): http://www.sagestep.org
- University of Idaho, Department of Rangeland Ecology and Management: http://www.cnr.uidaho.edu/range
- USDA Forest Service Fire and Environmental Research Applications team (FERA): http://www.fs.fed.us/pnw/fera/
- Natural Fuels Photo Series (Digital): http://depts.washington.edu/nwfire/dps/

References

Agee, J.K. 1993. Fire Ecology and Pacific Northwest Forests. Washington D.C.: Island Press. 493p.

Anderson, H.E. 1982. Aids to determining fuel models for estimating fire behavior. U.S. Department of Agriculture Forest Service. GTR-PSW-118.

Bonham, C.D. 1989. Measurement for Terrestrial Vegetation. New York, NY: John Wiley and Sons. Inc. 338p.

Bradford, J.B. and W.K. Lauenroth. 2006. Controls over invasion of Bromus tectorum: The importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science 17:693–704.

Brown, J.K. 1974. Handbook for inventorying downed woody material. INT-GTR-16. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 26p.

Brown, J.K. 1982. Fuel and fire behavior prediction in big sagebrush. Research paper INT-290. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10p.

Brown, J.K., R.D. Oberheu, and C.M. Johnston. 1982. Handbook for inventorying surface fuels and biomass in the Interior West. National Wildfire Coordinating Group NFES-2125. 48p.

Davis, K.P. 1959. Forest Fire: Control and Use. New York: McGraw-Hill.

Eyre. F.H. 1980. Forest Cover Types of the United States and Canada. Washington, D.C.: Society of American Foresters.

Kimmins, J.P. 1987. Forest Ecology. New York, NY: MacMillan Publishing Company.

Krebs, C.J. 1999. Ecological Methodology. New York, NY: Harper and Row.

McIver, J., H. Barrett, M. Brunson, S. Bunting, J. Chambers, C. D'Antonio, P. Doescher, S. Karl, S. Knick, R. Miller, M. Pellant, F. Pierson, D. Pyke, K. Rollins, B. Roundy, G. Schupp, R. Tausch, D. Turner, and M. Wisdom. A Regional Experiment to Evaluate Effects of Fire and Fire Surrogate Treatments in the Sagebrush Biome. 16 February 2005. <http://www.sagestep.org/pdfs/SageSTEP_proposal.pdf> Accessed 26 June 2008.

Miller, M. Fire Effects Guide: Chapter III – Fuels. 31 May 2001. <http://www.nwcg.gov/pms/RxFire/FEG.pdf> Accessed 26 June 2008.

Miller, R.F., J.D. Bates, T.J. Svejcar, F.B. Pierson, and L.E. Eddleman. 2005. Biology, ecology and management of Western Juniper (Juniperus occidentalis). Oregon State University Agricultural Experiment Station. Technical Bulletin 152. 79p.

Miller, R.F., and R.J. Tausch. 2001. The role of fire in pinyon and juniper woodlands: A descriptive analysis. Pages 15–30 in K.E.M. Galley and T.P. Wilson, editors. Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species. Tall Timbers Research Station Miscellaneous Publication 11.

Miller, R., R. Tausch, and W. Waichler. 1999. Old-growth juniper and pinyon woodlands. Pages 375-384 in S.B. Monsen and R. Stevens, compilers. Proceedings: Ecology and management of pinyon-juniper communities within the interior west. USDA Forest Service Rocky Mountain Research Station Proceedings RMRS-P-9.

Mutch, R.W. 1967. Cheatgrass coloration—a key to flammability? Journal of Range Management 20(4):259–300.

Noss, R.F., E.T. LaRoe III, and J.M. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. National Biological Service Biological Report 28, National Biological Service, Washington D.C., USA.

Odum, E.P. 1971. Fundamentals in Ecology 3rd Edition. Philadelphia: WB Saunders Company. 574p.

Olson, S. Threats to Sagebrush Ecosystems. 20 June 2008. <http://www.sagestep.org/threats.html> Accessed 26 June 2008.

Ottmar, R.D., R.E. Vihnanek, and J.D. Regelbrugge. 2000. Stereo photo series for quantifying natural fuels. Volume IV: Pinyon-juniper, sagebrush, and chaparral types in the Southwestern United States. PMS-833. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 97p.

Ottmar, R.D., D.V. Sandberg, C.L. Riccardi, and S.J. Prichard. 2007. An overview of the Fuels Characteristic Classification System—Quantifying, classifying, and creating fuelbeds for resource planning. Canadian Journal of Forest Research 37:2383–2393.

Pechanec, J.F. and G.D. Pickford. 1937. A weight-estimation method for the determination of range or pasture production. Journal of American Society of Agronomists 29: 894–904.

Pellant, M. 1994. History and applications of the Intermountain greenstripping program. INT-GTR-313. USDA Forest Service, Intermountain Research Station. pp. 63–68.

Peters, E.F. and S.C. Bunting. 1994. Fire conditions pre- and post-occurrence of annual grasses on the Snake River Plains. In: Monsen, Stephen B.; Kitchen, Stanley G., compilers. Proceedings: ecology and management of annual rangelands; 1992 May 18–22; Boise, ID. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. pp. 31–36.

Reinhardt, E., J. Scott, K. Gray, and R. Keane. 2006. Estimating canopy fuel characteristics in fire conifer stands in the western United States using tree and stand measurements. Canadian Journal of Forest Research 36:2803–2814.

Riccardi, C.L., R.D. Ottmar, D.V. Sandberg, A. Andrew, E. Elman, K. Kopper and J. Long. 2007. The fuelbed: a key element of the Fuel Characteristic Classification System. Canadian Journal of Forest Research 37(12):2394–2412.

Riser, P.G. 1984. Method of inventory and monitoring of vegetation, litter, and soil surface condition. Developing strategies for rangeland monitoring. National Research Council National Academy of Sciences.

Rittenhouse, L.R. and F.A. Sneva. 1977. A technique or estimating big sagebrush production. Journal of Range Management 30:68–70.

Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. Research Paper. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experimental Station. 40p.

Sabin, B.S. 2008. Relationship between allometric variables and biomass in Western Juniper (Juniperus occidentalis). MS Thesis, Oregon State University, Corvallis, OR.

Sandberg, D.V., R.D. Ottmar, and G.H. Cushon. 2001. Characterizing fuels in the 21st century. International Journal of Wildland Fire 10:381–387.

Salzer, D.W. 1994. An introduction to sampling and sampling design for vegetation monitoring. Unpublished papers prepared by BLM Training Course 1730-5. BLM training center, Phoenix, AZ.

Schroeder, M.J. and C.C. Buck. 1970. Fire weather: A guide for application of meteorological information to forest fire control operations. US Department of Agriculture, Washington, DC, Agricultural Handbook 360.

Scott, J.H. and R.E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72p.

Scott, J.H. and E.D. Reinhardt. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Research Paper. RMRS-RP-29. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 66p.

Shiflet, T.N. 1994. Rangeland Cover Types of the United States. Denver, CO: Society for Range Management.

Tausch, R.J. 2008. A structurally based analytic model for estimation of biomass and fuel loads of woodland trees. Submitted: Natural Resource Modeling.

United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). USDA Plants Database. 14 August 2008. <http://www.plants.usda.gov/index.html.> Accessed 14 August 2008.

USDA NRCS 1997. National Range and Pasture Handbook. USDA Natural Resources Conservation Service. Grazing Lands Technology Institute.

Whisenanat, S.G. 1990. Changing fire frequencies on Idaho's Snake River Plains: Ecological and Management Implications. In: McArthur, ED, EM Romney, SD Smith, PT Tueller, compilers. Proceedings: Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. INT-GTR-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. pp 4–10.

Whittaker, R.H. 1975. Communities and Ecosystems. New York, NY: MacMillan Publishing Company.

Wright, C.S. 2008. Personal Communication. Research Forester, USDA Forest Service, Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory, Seattle, WA.

Sagebrush Steppe Fuels Guide: 4 Groups
User Notes

Site Notes

- Four groups represent the SageSTEP Sagebrush/Cheatgrass sites characterized by the Loamy 10–12” ecological type (NRCS 1997).
- General site information includes: average annual precipitation ranges between 8.5–12.8 in. averaging 11 in., slopes (0–10%), all aspects, ‘loamy’ soil texture, and soil depths >20 in. with minimal stoniness.
- Prior to cheatgrass invasion, typical fire return interval on these sites was from several decades to 100 years. Since the introduction of cheatgrass the fires have been larger, often with a return interval of less than 10 years.
- Rock Creek and Gray Butte are the only sites that are not within active grazing allotments. All other subplots may have been grazed.

Guide Notes

1. Groups are organized by total shrub and total grass cover, perennial and annual grass combined.
    - Group 1: Shrub cover = 0–25%; Total grass cover = 0–25%
    - Group 2: Shrub cover = 0–25%: Total grass cover = >25%
    - Group 3: Shrub cover = >25%; Total grass cover = 0–25%
    - Group 4: Shrub cover = >25%: Total grass cover = >25%
2. The caption above the photos denotes measured percent cover by fuel stratum for that photo.
3. Sampling took place between April and August in 2006 and 2007. The date of the photo is in the lower right hand corner.
4. Percent bare ground is the only reported measure of fuel continuity.
5. Dominant graminoids include: ACHY, ACTH7, BRTE, ELEL5, HECO26, LECI4, PASM, POCU3, POSE, and PSSPS.
6. BRTE is the only annual grass reported with the exception of a small amount of BRAR5 found in Group 2.
7. Shrub loadings are restricted by height, longest diameter, perpendicular diameter and volume. Refer to Appendix VI, Sagebrush Steppe, for sample ranges used in this study and R^2 values.
8. Minimum values presented with an asterisk (*) indicate minimum value when present. Mean value includes all subplots.
9. The designation of “NA” indicates data were not available.
10. Tables of species codes and metric conversions can be found in Appendix I and III.

Sagebrush Steppe: Group 1 (Shrub: 0–25%; Total grass: 0–25%)

Shrubs: 14% Perennial Grass: 3% Total Grass: 6% Bare Ground: 49%

06/30/07

Shrubs: 15% Perennial Grass: 18% Total Grass: 18% Bare Ground: 36%

08/06/06

Site Locations: Hart Mountain, Onaqui, Owyhee, Roberts, Saddle Mountain; 137 subplots
Elevation Range: 879–5531 feet

SRM Cover Type: 403 – Wyoming Big Sagebrush
Fuel Model: GS1

Shrubs: 24% Perennial Grass: 3% Total Grass: 23% Bare Ground: 35%

07/09/06

Shrubs: 22% Perennial Grass: 4% Total Grass: 11% Bare Ground: 43%

07/21/06

Sagebrush Steppe: Group 1 (Shrub: 0–25%; Total grass: 0–25%)

SHRUBS

Species	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^2)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRW8	6	25	16	1	97	18	863	17487	5136	0.06	9.04	2.42	0.0063	0.1599	0.0449
CHVI8	<1*	6	1	2	32	8	23*	522	8	<0.01	0.21	0.06	0.0001	0.0111	0.0025

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	1	24	11
Total cover: Annual grass (%)	<1*	22	5
Total cover: Forbs (%)	<1*	32	4
Grass height (in.)	1	11	5
Forb height (in.)	1*	6	2
Live herbaceous loading (lbs/ac)	4.48	353.66	41.62
Dead herbaceous loading (lbs/ac)	4.48*	317.85	49.00
Total herbaceous loading (lbs/ac)	8.96	617.51	90.62
Bulk density (lbs/ft^3)	0.0036	0.0812	0.0252

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.09*	0.78	0.31
1.1–3.0 (100-hour)	0.05*	2.41	0.48
3.1–9.0 (1000-hour: Sound)	0.61*	15.68	0.73
3.1–9.0 (1000-hour: Rotten)	0.45*	1.15	0.06
Total	1.20*	20.02	1.58

LITTER

	Total cover (%)			Total loading (ton/ac)		
	Min	Max	Mean	Min	Max	Mean
Interspace litter	4	35	17	<0.01	0.65	0.08
Bare ground	16	82	40	NA		

Sagebrush Steppe: Group 2 (Shrub: 0–25%; Total grass: >25%)

SHRUBS

Species	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^2)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRW8	<1*	26	15	2	189	25	68*	6518	2288	0.16	7.84	2.00	0.0002	0.0932	0.0256
CHVI8	<1*	10	1	3	59	12	23*	5428	50	<0.01	0.37	0.05	<0.0001	0.0108	0.0020

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	3	45	22
Total cover: Annual grass (%)	1*	75	18
Total cover: Forbs (%)	<1*	43	8
Grass height (in.)	1	16	7
Forb height (in.)	1*	9	3
Live herbaceous loading (lbs/ac)	4.48	1308.99	265.18
Dead herbaceous loading (lbs/ac)	4.48*	1844.41	160.22
Total herbaceous loading (lbs/ac)	8.96*	3153.40	425.40
Bulk density (lbs/ft^3)	0.0077	0.2615	0.0455

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	1.19	0.29
1.1–3.0 (100-hour)	0.05*	1.77	0.45
3.1–9.0 (1000-hour: Sound)	0.46*	14.82	0.95
3.1–9.0 (1000-hour: Rotten)	0.18*	1.73	0.06
Total	0.70*	19.51	1.75

LITTER

	Total cover (%)			Total loading (ton/ac)		
	Min	Max	Mean	Min	Max	Mean
Interspace litter	4	36	14	<0.01	0.95	0.15
Bare ground	3	89	27	NA		

Sagebrush Steppe: Group 2 (Shrub: 0–25%; Total grass: >25%)

Shrubs: 16% Perennial Grass: 33% Total Grass: 45% Bare Ground: 82%

08/06/06

Shrubs: 8% Perennial Grass: 16% Total Grass: 56% Bare Ground: 16%

07/07/06

Site Locations: Hart Mountain, Moses Coulee, Onaqui, Owyhee, Roberts, Saddle Mountain; 213 subplots

SRM Cover Type: 403 – Wyoming Big Sagebrush
Fuel Model: GS1 or GS2
Elevation Range: 846–5531 feet

Shrubs: 23% Perennial Grass: 30% Total Grass: 58% Bare Ground: 5%

05/26/06

Shrubs: 24% Perennial Grass: 14% Total Grass: 28% Bare Ground: 31%

07/07/06

Sagebrush Steppe: Group 3 (Shrub: >25%; Total grass: 0–25%)

Shrubs: 25% Perennial Grass: 13% Total Grass: 36% Bare Ground: 24%

08/20/06

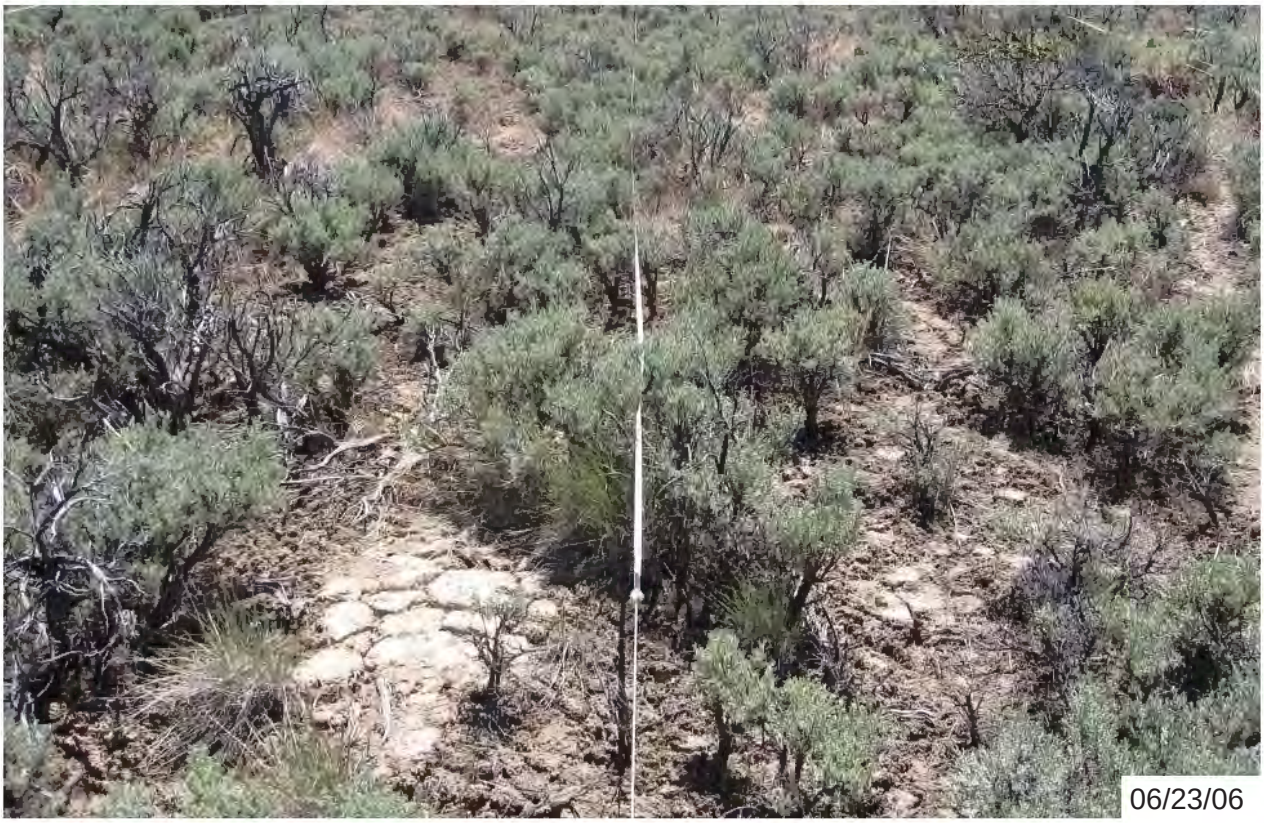
Shrubs: 31% Perennial Grass: 9% Total Grass: 13% Bare Ground: 37%

07/21/06

Site Locations: Hart Mountain, Onaqui, Owyhee, Roberts, Saddle Mountain; 83 subplots
Elevation Range: 846–5531 feet

SRM Cover Type: 403 – Wyoming Big Sagebrush
Fuel Model: GS1 or SH1

Shrubs: 35% Perennial Grass: 21% Total Grass: 21% Bare Ground: 34%



06/23/06

Shrubs: 45% Perennial Grass: 9% Total Grass: 9% Bare Ground: 30%

06/25/06

Sagebrush Steppe: Group 3 (Shrub: >25%; Total grass: 0–25%)

SHRUBS

Species	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^2)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRW8	12	61	33	3	62	20	1590	14057	5113	0.47	17.16	4.67	0.0114	0.5907	0.1606
CHVI8	<1*	15	1	1	41	12	23*	2180	109	0.01	1.19	0.38	0.0001	0.0003	0.0001

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	<1*	23	10
Total cover: Annual grass (%)	<1*	18	3
Total cover: Forbs (%)	<1*	48	4
Grass height (in.)	1*	14	5
Forb height (in.)	<1*	6	1
Live herbaceous loading (lbs/ac)	4.48	311.58	52.63
Dead herbaceous loading (lbs/ac)	4.48*	350.97	33.01
Total herbaceous loading (lbs/ac)	8.92	662.55	85.64
Bulk density (lbs/ft^3)	0.0043	0.0749	0.0210

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.08	1.03	0.36
1.1–3.0 (100-hour)	0.20*	2.02	0.74
3.1–9.0 (1000-hour: Sound)	0.24*	9.00	1.16
3.1–9.0 (1000-hour: Rotten)	0.45*	2.31	0.20
Total	0.97*	14.36	2.46

LITTER

	Total cover (%)			Total loading (ton/ac)		
	Min	Max	Mean	Min	Max	Mean
Interspace litter	5	26	14	<0.01	0.22	0.03
Bare ground	14	52	32	NA		

Sagebrush Steppe: Group 4 (Shrub: >25%; Total grass: >25%)

SHRUBS

Species	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^2)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRW8	20	47	30	2	70	25	1295	8925	3696	0.08	5.67	1.40	0.0012	0.0480	0.0167
CHVI8	<1*	6	<1	5	58	12	23*	1385	39	<0.01	0.04	0.01	<0.0001	0.0014	0.0004

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	4	48	25
Total cover: Annual grass (%)	<1*	64	13
Total cover: Forbs (%)	<1*	41	9
Grass height (in.)	2	14	6
Forb height (in.)	1*	21	1
Live herbaceous loading (lbs/ac)	8.95	682.25	121.78
Dead herbaceous loading (lbs/ac)	4.48	750.30	55.70
Total herbaceous loading (lbs/ac)	13.43	1432.55	177.48
Bulk density (lbs/ft^3)	0.0029	0.1994	0.0284

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	0.88	0.30
1.1–3.0 (100-hour)	0.05*	1.57	0.53
3.1–9.0 (1000-hour: Sound)	0.24*	252.88	2.71
3.1–9.0 (1000-hour: Rotten)	0.45*	2.56	0.09
Total	0.75*	257.89	3.63

LITTER

	Total cover (%)			Total loading (ton/ac)		
	Min	Max	Mean	Min	Max	Mean
Interspace litter	2	31	11	<0.01	0.79	0.07
Bare ground	4	40	20	NA		

Sagebrush Steppe: Group 4 (Shrub: >25%; Total grass: >25%)

Shrubs: 26% Perennial Grass: 6% Total Grass: 69% Bare Ground: 9%

04/25/07

Shrubs: 29% Perennial Grass: 27% Total Grass: 30% Bare Ground: 22%

05/10/07

Site Locations: Hart Mountain, Moses Coulee, Onaqui, Owyhee, Roberts, Saddle Mountain; 151 subplots

SRM Cover Type: 403 – Wyoming Big Sagebrush
Fuel Model: GS1, GS2 or SH1
Elevation Range: 846–5531 feet

Shrubs: 37% Perennial Grass: 15% Total Grass: 36% Bare Ground: 15%

06/04/07

Shrubs: 45% Perennial Grass: 33% Total Grass: 39% Bare Ground: 18%

05/13/07

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Pinyon-Juniper Fuels Guide: 3 Phases
User Notes

Site Notes

- Three phases represent the SageSTEP Sagebrush/Pinyon-Juniper sites characterized by the Loamy 12–14” ecological type (NRCS 1997).
- General site information includes: average annual precipitation ranged between 10.2–15.8 in. averaging 13.5 in., slopes 6–30%, all aspects, ‘loamy’ soil texture, and soil depths >20 in. with minimal stoniness.
- The historical fire return interval on these sites was 30–40 years. The amount of woodland encroachment suggests these sites have not burned since the late 1800s. With increased woodland dominance the fire regime has shifted to infrequent, high intensity fires.
- All sites are in active grazing allotments, and all subplots may have been grazed.

Guide Notes

1. Phases are organized by tree stand cover and understory characteristics.
   - Phase 1: Trees are present on the site, but the shrub and herb layer are the dominant influence on ecological processes (hydrologic, nutrient, and energy cycles).
   - Phase 2: Trees are co-dominant with shrub and herb layers. All three layers influence ecological processes.
   - Phase 3: Trees are the dominant vegetation and the primary layer influencing ecological processes.
2. The caption above the photos denotes measured percent cover by fuel stratum for that photo.
3. Sampling took place between May and July in 2006 and 2007. The date of the photo is in the lower right hand corner.
4. Percent bare ground is the only reported measure of fuel continuity.
5. Dominant graminoids include: ACHY, ACNE10, ACTH7, BRTE, HECO26, POSE, and PSSPS.
6. BRTE is the only annual grass reported.
7. Shrub loadings are restricted by height, long diameter, perpendicular diameter and volume. Refer to Appendix VI, Pinyon-Juniper, for sample ranges used in this study and R^2 values.
8. Minimum values presented with an asterisk (*) indicate minimum value when present. Mean value includes all subplots.
9. The designation of “NA” indicates data were not available.
10. Tables of species codes and metric conversions can be found in Appendix I and III.

Pinyon-Juniper: Phase 1

Trees: 3% Shrubs: 16% Perennial Grass: 31% Total Grass: 31% Bare Ground: 23%

07/13/07

Trees: 5% Shrubs: 25% Perennial Grass: 13% Total Grass: 14% Bare Ground: 23%

07/01/07

Site Locations: Marking Corral, Spruce Mountain, South Ruby Mountain, Seven Mile; 63 subplots
Elevation Range: 6565–7766 feet

SRM Cover Type: 403 – Wyoming Big Sagebrush or 405 – Black Sagebrush
Fuel Model: GS1, SH1, or TU1

Trees: 7% Shrubs: 17% Perennial Grass: 13% Total Grass: 13% Bare Ground: 29%

07/01/07

Trees: 10% Shrubs: 10% Perennial Grass: 16% Total Grass: 16% Bare Ground: 25%

06/30/07

Pinyon-Juniper: Phase 1

TREES

	JUOS			CELE3			PIMO		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Total cover (%)	<1	30	6	<1*	7	< 1	<1*	13	3
Density: <1.6 ft tall (stem/ac)	23*	727	29	23*	68	1	23*	363	29
Density: ≥1.6 ft tall (stem/ac)	8	221	77	4*	29	1	4*	135	31
Height (ft)	4	11	7	2	16	9	2	13	6
Height to live crown (ft)	<1*	11	1	5*	8	3	<1*	4	1
Live loading (ton/ac)	0.02	14.84	2.23	NA			<0.01	6.11	1.09
Dead loading (ton/ac)	<0.01*	1.21	0.13				<0.01*	0.55	0.07
Available loading (ton/ac)	0.01	5.37	1.00				<0.01	2.44	0.46
Canopy bulk density (lbs/ft^3)	0.0001	0.0203	0.0049				<0.0001	0.0085	0.0017

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	NA			NA			NA			NA			NA		
ARNO4	1*	33	8	3	37	13	45*	20780	3140	0.01	2.30	1.02	0.0001	0.0822	0.0348
ARTRV	<1*	19	1	6	66	20	24	3478	1502	0.01	3.27	0.98	0.0007	0.0349	0.0123
ARTRW8	<1*	22	7	1	72	25	45*	4542	1633	0.10	8.08	1.75	0.0003	0.0500	0.0159
CHVI8	<1*	14	3	1	44	12	24	5870	1382	<0.01	0.41	0.09	<0.0001	0.0147	0.0038
PUTR2	<1*	12	2	7	83	37	23*	954	120	<0.01	2.20	0.55	0.0002	0.0113	0.0044

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	1	45	16
Total cover: Annual grass (%)	<1*	17	1
Total cover: Forbs (%)	1*	17	7
Grass height (in.)	3	16	9
Forb height (in.)	2*	13	5
Live herbaceous loading (lbs/ac)	44.78	462.89	193.99
Dead herbaceous loading (lbs/ac)	4.48*	257.86	67.95
Total herbaceous loading (lbs/ac)	49.26*	720.75	261.94
Bulk density (lbs/ft^3)	0.0045	0.0310	0.0129

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	1.13	0.41
1.1–3.0 (100-hour)	0.05*	2.16	0.56
3.1–9.0 (1000-hour: Sound)	0.61*	22.06	1.76
3.1–9.0 (1000-hour: Rotten)	0.45*	7.34	0.71
Total	1.66*	32.69	3.44

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			< 0.1	3.1	1.3	0.02	6.76	1.48	0.0812	2.0727	0.5012
Tree duff	NA			< 0.1	0.9	0.2	0.01	3.73	0.64	0.0750	2.9280	0.9259
Interspace litter	8	38	20	NA			0.01	0.78	0.15	NA		
Bare ground	10	61	32	NA			NA			NA		

Pinyon-Juniper: Phase 2

Trees: 13% Shrubs: 24% Perennial Grass: 17% Total Grass: 17% Bare Ground: 20%

07/01/07

Trees: 20% Shrubs: 8% Perennial Grass: 3% Total Grass: 3% Bare Ground: 55%

06/17/07

Site Locations: Marking Corral, Spruce Mountain, South Ruby Mountain, Seven Mile; 90 subplots
Elevation Range: 6565–7766 feet
Fuel Model: SH1 or TU1

SRM Cover Types: 403 – Wyoming Big Sagebrush, 405 – Black Sagebrush, 412 – Juniper-pinyon Woodland
SAF Cover Types: 239 – Pinyon-Juniper

Trees: 27% Shrubs: 10% Perennial Grass: 13% Total Grass: 13% Bare Ground: 54%

05/29/07

Trees: 33% Shrubs: 10% Perennial Grass: 11% Total Grass: 11% Bare Ground: 26%

05/24/07

Pinyon-Juniper: Phase 2

TREES

	JUOS			CELE3			PIMO		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Total cover (%)	<1	46	14	<1*	33	1	<1*	38	11
Density: <1.6 ft tall (stem/ac)	23*	727	43	23*	68	1	23*	1090	125
Density: ≥1.6 ft tall (stem/ac)	4*	352	106	4*	147	4	4*	270	91
Height (ft)	3	14	8	2	16	7	2	12	7
Height to live crown (ft)	<1*	8	1	<1*	8	4	<1*	12	1
Live loading (ton/ac)	0.01	17.21	5.36	NA			< 0.01	14.34	4.24
Dead loading (ton/ac)	<0.01*	1.35	0.34				< 0.01*	1.44	0.30
Available loading (ton/ac)	0.01	7.47	2.26				< 0.01	6.01	1.78
Canopy bulk density (lbs/ft³)	0.0001	0.0304	0.0099				<0.0001	0.0239	0.0067

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft³)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	<1*	9	<1	5	17	9	161	1452	677	0.02	0.35	0.12	0.0012	0.0167	0.0057
ARNO4	<1*	28	5	<1	88	12	23*	11900	2293	0.01	2.30	0.75	0.0055	0.0674	0.0263
ARTRV	<1*	10	<1	7	32	17	24	1957	557	<0.01	0.90	0.25	0.0003	0.0177	0.0041
ARTRW8	<1*	18	5	2	65	19	23*	4769	1363	0.02	4.09	1.05	0.0001	0.0425	0.0140
CHVI8	<1*	7	1	6	28	11	24	3478	603	<0.01	0.19	0.03	<0.0001	0.0088	0.0014
PUTR2	<1*	11	2	2	93	31	23*	704	143	0.03	2.14	0.53	0.0009	0.0105	0.0044

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	<1	28	11
Total cover: Annual grass (%)	<1*	4	<1
Total cover: Forbs (%)	<1	23	5
Grass height (in.)	3	12	7
Forb height (in.)	1	11	4
Live herbaceous loading (lbs/ac)	21.49	504.08	132.58
Dead herbaceous loading (lbs/ac)	2.69	465.58	51.32
Total herbaceous loading (lbs/ac)	24.18	969.66	183.90
Bulk density (lbs/ft^3)	0.0027	0.1365	0.0121

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.08	1.26	0.49
1.1–3.0 (100-hour)	0.05	2.02	0.56
3.1–9.0 (1000-hour: Sound)	0.61*	17.21	2.43
3.1–9.0 (1000-hour: Rotten)	0.01*	8.62	0.58
Total	0.74*	19.11	4.06

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.9	3.4	1.9	1.06	11.92	4.94	0.4370	2.8842	1.4066
Tree duff	NA			<0.1	13.1	0.5	0.02	15.85	2.12	0.2497	6.3366	2.2395
Interspace litter	8	55	25	NA			<0.01*	0.85	0.10	NA		
Bare ground	7	62	40	NA			NA			NA		

Pinyon-Juniper: Phase 3

Trees: 33% Shrubs: 4% Perennial Grass: 6% Total Grass: 6% Bare Ground: 39%

05/22/07

Trees: 41% Shrubs: 5% Perennial Grass: 1% Total Grass: 1% Bare Ground: 40%

06/26/07

Site Locations: Marking Corral, Spruce Mountain, South Ruby Mountain, Seven Mile; 62 subplots
Elevation Range: 6565–7766 feet

SRM Cover Types: 412 – Juniper-Pinyon Woodland
SAF Cover Types: 239 – Pinyon-Juniper
Fuel Model: TU1

Trees: 45% Shrubs: <1% Perennial Grass: 0% Total Grass: 0% Bare Ground: 41%

06/13/07

Trees: 53% Shrubs: 0% Perennial Grass: 1% Total Grass: 1% Bare Ground: 17%

07/02/07

Pinyon-Juniper: Phase 3

TREES

	JUOS			CELE3			PIMO		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Total cover (%)	2	76	29	1*	30	2	<1*	46	22
Density: <1.6 ft tall (stem/ac)	23*	727	39	23*	182	4	23*	2067	292
Density: ≥1.6 ft tall (stem/ac)	12*	433	136	4*	208	11	4*	397	144
Height (ft)	7	15	11	4	15	9	2	22	10
Height to live crown (ft)	<1*	16	2	<1*	10	2	<1*	15	2
Live loading (ton/ac)	0.88	35.84	11.81	NA			<0.01	19.45	9.53
Dead loading (ton/ac)	0.06	3.08	0.86				0.02*	2.51	0.83
Available loading (ton/ac)	0.34	12.44	4.74				0.01*	8.20	4.04
Canopy bulk density (lbs/ft³)	0.0014	0.0387	0.0170				0.0001*	0.0279	0.0130

SHRUBS

	Total cover (%)			Height (in)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft³)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	<1*	2	<1	5	17	8	167	382	251	0.04	0.10	0.06	0.0020	0.0054	0.0033
ARNO4	<1*	12	1	6	55	12	23*	4565	286	<0.01	0.30	0.13	0.0005	0.0135	0.0043
ARTRV	1*	4	<1	7	37	16	24	1129	213	<0.01	0.60	0.13	0.0002	0.0102	0.0023
ARTRW8	<1*	7	1	6	44	17	23*	2067	460	0.01	0.63	0.23	0.0002	0.0087	0.0036
CHVI8	<1*	2	<1	6	24	11	10	358	120	<0.01	0.02	0.01	<0.0001	0.0009	0.0003
PUTR2	<1*	10	1	2	68	22	23*	613	87	<0.01	0.84	0.21	0.0002	0.0082	0.0031

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	<1*	20	4
Total cover: Annual grass (%)	<1*	13	1
Total cover: Forbs (%)	<1*	25	2
Grass height (in.)	2*	12	5
Forb height (in.)	1*	7	3
Live herbaceous loading (lbs/ac)	2.69*	552.43	72.86
Dead herbaceous loading (lbs/ac)	1.79*	326.80	32.59
Total herbaceous loading (lbs/ac)	4.48*	879.23	105.45
Bulk density (lbs/ft^3)	0.0006	0.0471	0.0095

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.06	1.13	0.35
1.1–3.0 (100-hour)	0.05	1.48	0.49
3.1–9.0 (1000-hour: Sound)	0.61*	56.50	7.20
3.1–9.0 (1000-hour: Rotten)	0.45*	37.44	0.98
Total	1.17*	96.55	9.02

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			1.0	3.3	1.9	3.45	20.53	9.29	1.2236	5.7872	2.6971
Tree duff	NA			<0.1	1.6	0.4	0.24	22.47	4.46	1.8666	10.9626	4.7131
Interspace litter	18	82	46	NA			<0.01*	0.57	0.04	NA		
Bare ground	13	63	37	NA			NA			NA		

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Utah Juniper Fuels Guide: 3 Phases
User Notes

Site Notes

- Three phases represent the SageSTEP Sagebrush/Utah Juniper sites characterized by the Loamy 12–14” ecological type (NRCS 1997).
- General site information includes: average annual precipitation ranges between 12.7–17.5 in. averaging 14.9 in., slopes 3–33%, all aspects, ‘loamy’ soil texture, and soil depths >20 in. with minimal stoniness.
- The historical fire return interval on these sites was 20 to greater than 100 years. The amount of woodland encroachment suggests these sites have not burned since the late 1800s. With increased woodland dominance the fire regime has shifted to infrequent, high intensity fires.
- Onaqui is the only site with an active grazing allotments. Some of these subplots may have been grazed. Scipio is located within a non-use grazing allotment. Stansbury and Greenville Bench are not currently grazed.

Guide Notes

1. Phases are organized by tree stand cover and understory characteristics.
    - Phase 1: Trees are present on the site, but the shrub and herb layer are the dominant influence on ecological processes (hydrologic, nutrient, and energy cycles).
    - Phase 2: Trees are co-dominant with shrub and herb layers. All three layers influence ecological processes.
    - Phase 3: Trees are the dominant vegetation and the primary layer influencing ecological processes.
2. The caption above the photos denotes measured percent cover by fuel stratum for that photo.
3. Sampling took place between May and early August in 2006 and 2007. The date of the photo is in the lower right hand corner.
4. Percent bare ground is the only reported measure of fuel continuity.
5. Dominant graminoids include: ACHY, ACNE10, ACTH7, BRTE, HECO26, POSE, and PSSPS.
6. BRTE is the only annual grass reported.
7. Shrub loadings are restricted by height, long diameter, perpendicular diameter and volume. Refer to Appendix VI, Utah Juniper, for sample ranges used in this study and R^2 values.
8. Minimum values presented with an asterisk (*) indicate minimum value when present. Mean value includes all subplots.
9. The designation of “NA” indicates data were not available.
10. Tables of species codes and metric conversions can be found in Appendix I and III.

Utah Juniper: Phase 1

Trees: 4% Shrubs: 23% Perennial Grass: 19% Total Grass: 20% Bare Ground: 33%

07/24/06

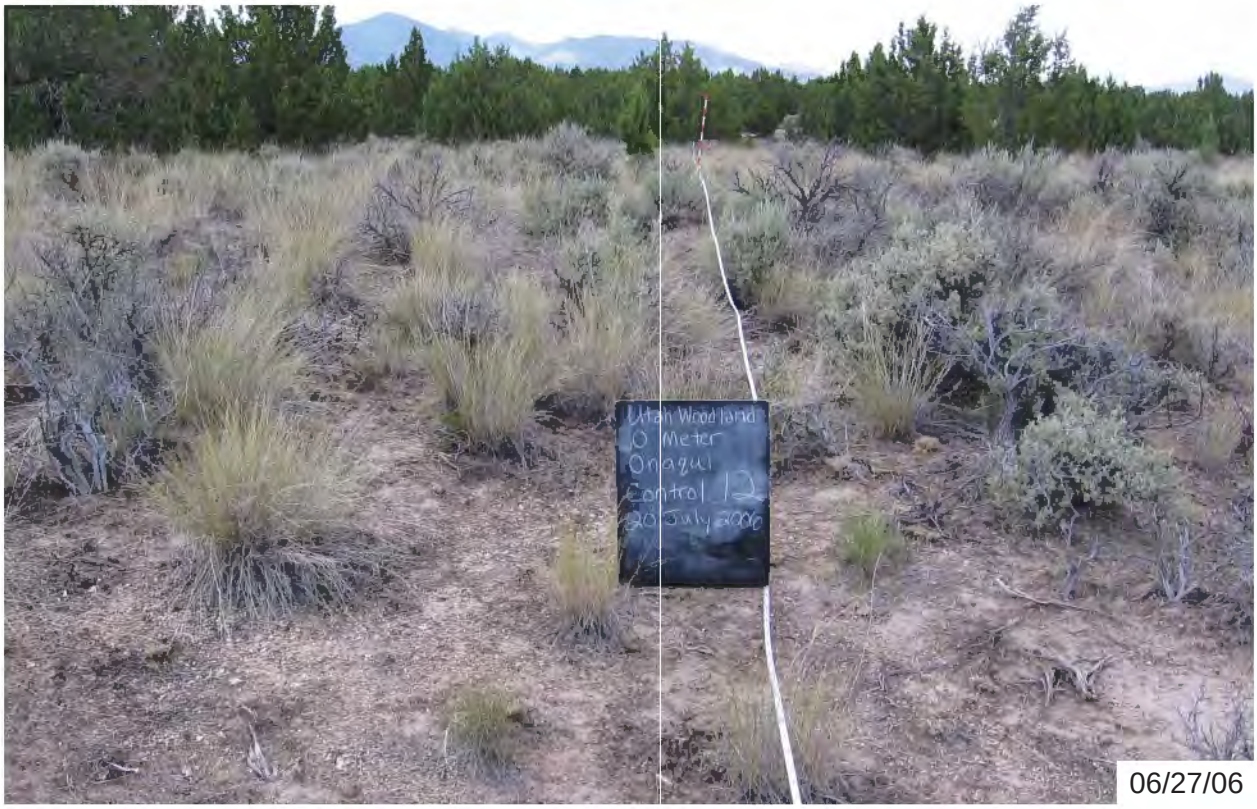
Trees: 5% Shrubs: 20% Perennial Grass: 16% Total Grass: 22% Bare Ground: 43%

08/01/06

Site Locations: Greenville Bench, Onaqui, Scipio, Stansbury; 65 subplots
Elevation Range: 5558–6024 feet

SRM Cover Types: 104 – Antelope bitterbrush-bluebunch wheatgrass
Fuel Model: SH1, SH2, or TU1

Trees: 11% Shrubs: 33% Perennial Grass: 23% Total Grass: 37% Bare Ground: 10%



06/27/06

Trees: 11% Shrubs: 10% Perennial Grass: 27% Total Grass: 27% Bare Ground: 24%

07/20/06

Utah Juniper: Phase 1

TREES

	JUOS			PIED		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	1	31	9	<1	9	1
Density: <1.6 ft tall (stem/ac)	23*	1453	117	23*	727	15
Density: ≥1.6 ft tall (stem/ac)	16*	143	50	4*	90	12
Height (ft)	4	15	9	3	10	7
Height to live crown (ft)	<1*	6	2	<1	6	2
Live loading (ton/ac)	0.11	11.70	2.81	<0.01	2.70	0.89
Dead loading (ton/ac)	<0.01*	1.04	0.21	<0.01*	0.19	0.06
Available loading (ton/ac)	0.06	4.38	1.22	<0.01	1.16	0.39
Canopy bulk density (lbs/ft^3)	0.0007	0.0200	0.0059	<0.0001*	0.0053	0.0009

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRV	<1*	29	5	6	65	28	23*	2316	325	0.06	8.24	2.96	0.0011	0.0686	0.0274
ARTRW8	3*	36	9	2	58	21	772*	4315	1741	0.13	7.23	2.18	0.0063	0.0748	0.0328
CHVI8	<1*	16	2	2	39	11	24	4783	1075	0.02	0.56	0.22	0.0008	0.0225	0.0081
PUTR2	5*	39	7	9	91	50	23*	2021	133	0.40	4.96	2.88	0.0069	0.0313	0.0167

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	2	49	17
Total cover: Annual grass (%)	<1*	65	17
Total cover: Forbs (%)	<1	40	10
Grass height (in.)	3	16	7
Forb height (in.)	1	13	4
Live herbaceous loading (lbs/ac)	9.85	544.37	146.39
Dead herbaceous loading (lbs/ac)	7.16	461.10	116.56
Total herbaceous loading (lbs/ac)	17.01	1005.47	262.95
Bulk density (lbs/ft^3)	0.0019	0.0434	0.0166

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	0.87	0.27
1.1–3.0 (100-hour)	0.10	2.85	0.52
3.1–9.0 (1000-hour: Sound)	0.46*	16.16	2.79
3.1–9.0 (1000-hour: Rotten)	0.58*	1.20	0.08
Total	1.15*	21.08	3.66

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.4	2.1	1.2	0.27	10.40	2.57	0.1873	3.5522	1.1765
Tree duff	NA			<0.1	0.5	0.2	0.04	3.43	0.64	0.2435	7.7288	2.1187
Interspace litter	3	34	15	NA			<0.01	0.24	0.04	NA		
Bare ground	2	49	23	NA			NA			NA		

Utah Juniper: Phase 2

Trees: 11% Shrubs: 11% Perennial Grass: 15% Total Grass: 15% Bare Ground: 43%

08/01/06

Trees: 17% Shrubs: 41% Perennial Grass: 12% Total Grass: 28% Bare Ground: 14%

06/14/06

Site Locations: Greenville Bench, Onaqui, Scipio, Stansbury; 90 subplots
Elevation Range: 5558–6024 feet
Fuel Model: SH1 or TU1

SRM Cover Types: 104 – Antelope bitterbrush-Bluebunch wheatgrass, 412 – Juniper-Pinyon woodland
SAF Cover Type: 239 – Pinyon-Juniper

Trees: 20% Shrubs: 4% Perennial Grass: 15% Total Grass: 18% Bare Ground: 30%

05/12/06

Trees: 34% Shrubs: 7% Perennial Grass: 8% Total Grass: 18% Bare Ground: 26%

07/06/06

Utah Juniper: Phase 2

TREES

	JUOS			PIED		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	<1	50	17	<1*	20	3
Density: <1.6 ft tall (stem/ac)	23*	363	18	23*	2180	23
Density: ≥1.6 ft tall (stem/ac)	4*	294	85	4*	180	20
Height (ft)	5	15	10	2	14	7
Height to live crown (ft)	<1*	7	3	<1	7	2
Live loading (ton/ac)	0.10	18.63	5.56	<0.01*	5.47	1.88
Dead loading (ton/ac)	<0.01	1.60	0.42	<0.01*	0.44	0.13
Available loading (ton/ac)	0.05	7.33	2.39	0.01*	2.41	0.83
Canopy bulk density (lbs/ft^3)	0.0006	0.0248	0.0106	0.0001*	0.0137	0.0016

SHRUBS

	Total cover (%)			Height (in)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRV	1*	30	2	6	77	27	45*	2407	180	0.05	6.39	2.50	0.0004	0.0518	0.0172
ARTRW8	<1*	25	6	3	110	21	182*	4020	1400	0.06	6.61	1.25	0.0001	0.0616	0.0200
CHVI8	<1*	11	1	5	34	11	24	5870	837	<0.01	0.52	1.15	<0.0001	0.0191	0.0055
PUTR2	<1*	30	3	7	89	45	23*	658	31	<0.01	4.54	1.56	0.0019	0.0225	0.0088

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	<1	43	16
Total cover: Annual grass (%)	<1*	50	12
Total cover: Forbs (%)	<1*	34	9
Grass height (in.)	2	15	6
Forb height (in.)	1	13	3
Live herbaceous loading (lbs/ac)	2.69	547.05	111.56
Dead herbaceous loading (lbs/ac)	2.69*	305.31	72.75
Total herbaceous loading (lbs/ac)	5.38*	852.36	184.31
Bulk density (lbs/ft^3)	0.0012	0.0387	0.0131

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.02	0.72	0.26
1.1–3.0 (100-hour)	0.05*	2.16	0.47
3.1–9.0 (1000-hour: Sound)	0.46*	51.23	3.69
3.1–9.0 (1000-hour: Rotten)	0.45*	7.27	0.33
Total	0.98*	61.38	4.75

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.6	2.2	1.2	0.47	18.01	4.72	0.2060	6.3054	2.2724
Tree duff	NA			<0.1*	0.7	0.1	0.06*	5.70	1.11	0.4432*	9.7765	3.0736
Interspace litter	4	36	17	NA			<0.01	0.25	0.04	NA		
Bare ground	3	57	29	NA			NA			NA		

Utah Juniper: Phase 3

Trees: 31% Shrubs: 5% Perennial Grass: 8% Total Grass: 40% Bare Ground: 26%

07/10/06

Trees: 24% Shrubs: 5% Perennial Grass: 3% Total Grass: 22% Bare Ground: 35%

07/17/06

Site Locations: Greenville Bench, Onaqui, Scipio, Stansbury; 81 subplots
Elevation Range: 5558–6024 feet

SRM Cover Types: 412 – Juniper-Pinyon Woodland
SAF Cover Types: 239 – Pinyon-Juniper
Fuel Model: TU1

Trees: 33% Shrubs: 2% Perennial Grass: 2% Total Grass: 2% Bare Ground: 59%

08/01/06

Trees: 48% Shrubs: 5% Perennial Grass: 6% Total Grass: 6% Bare Ground: 28%

08/03/06

Utah Juniper: Phase 3

TREES

	JUOS			PIED		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	9	65	28	<1	42	5
Density: <1.6 ft tall (stem/ac)	23*	2907	40	23*	1453	30
Density: ≥1.6 ft tall (stem/ac)	45*	490	147	4*	348	39
Height (ft)	7	15	10	6	15	9
Height to live crown (ft)	<1*	10	3	<1	8	3
Live loading (ton/ac)	2.75	19.79	8.92	0.06	11.79	3.95
Dead loading (ton/ac)	0.18	1.60	0.65	0.02*	0.85	0.28
Available loading (ton/ac)	1.30	9.92	3.98	0.03	5.24	1.75
Canopy bulk density (lbs/ft^3)	0.0062	0.0417	0.0175	<0.0001*	0.0240	0.0031

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARTRV	<1*	11	1	6	55	22	182*	1385	152	0.02	1.74	0.62	0.0005	0.0176	0.0078
ARTRW8	<1*	12	2	4	57	20	23*	3021	550	0.01	2.26	0.52	0.0003	0.0347	0.0092
CHVI8	<1*	4	< 1	6	27	9	24	1344	248	<0.01	0.05	0.02	<0.0001	0.0018	0.0007
PUTR2	1*	20	2	7	73	40	23*	1295	51	0.01	2.27	0.67	0.0003	0.0105	0.0039

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	<1*	33	12
Total cover: Annual grass (%)	<1*	38	9
Total cover: Forbs (%)	<1	39	8
Grass height (in.)	2	17	6
Forb height (in.)	1	24	3
Live herbaceous loading (lbs/ac)	2.69	255.17	66.15
Dead herbaceous loading (lbs/ac)	2.69	240.85	45.01
Total herbaceous loading (lbs/ac)	5.38	496.02	111.16
Bulk density (lbs/ft^3)	0.0007	0.0418	0.0093

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.04	0.57	0.23
1.1–3.0 (100-hour)	0.05	1.53	0.45
3.1–9.0 (1000-hour: Sound)	0.61*	57.70	4.72
3.1–9.0 (1000-hour: Rotten)	0.45*	2.80	0.27
Total	1.15*	62.60	5.67

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.6	2.1	1.2	2.14	18.01	8.12	1.2548	7.7850	3.8425
Tree duff	NA			<0.1	0.9	0.2	0.11	10.86	1.89	1.4983	22.6682	6.3667
Interspace litter	8	55	21	NA			<0.01	0.07	0.02	NA		
Bare ground	6	68	34	NA			NA			NA		

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Western Juniper Fuels Guide: 3 Phases
User Notes

Site Notes

- Three phases represent the SageSTEP Sagebrush/Western Juniper sites characterized by the Loamy 12–14” ecological type (NRCS 1997).
- General site information includes: average annual precipitation ranges between 10.2–19.4 in. averaging 14.4 in., slopes 0–41%, all aspects, ‘loamy’ soil texture, and soil depths > 20 in. with minimal stoniness.
- The historical fire return interval on these sites was 10–70 years with low to moderate severity fires. The amount of woodland encroachment suggests these sites have not burned since the late 1800s. With increased woodland dominance the fire regime has shifted to infrequent, high intensity fires.
- Bridge Creek is the only site without an active grazing allotments and has not been grazed. All other subplots may have been grazed.

Guide Notes

1. Phases are organized by tree stand cover and understory characteristics.
    - Phase 1: Trees are present on the site, but the shrub and herb layer are the dominant influence on ecological processes (hydrologic, nutrient, and energy cycles).
    - Phase 2: Trees are co-dominant with shrub and herb layers. All three layers influence ecological processes.
    - Phase 3: Trees are the dominant vegetation and the primary layer influencing ecological processes.
2. The caption above the photos denotes measured percent cover by fuel stratum for that photo.
3. Sampling took place between May and early August in 2006 and 2007. The date of the photo is in the lower right hand corner.
4. Percent bare ground is the only reported measure of fuel continuity.
5. Dominant graminoids include: ACHY, ACNE10, ACTH7, BRTE, HECO26, POSE, and PSSPS.
6. BRTE is the only annual grass reported.
7. Shrub loadings are restricted by height, long diameter, perpendicular diameter and volume. Refer to Appendix VI, Western Juniper, for sample ranges used in this study and R^2 values.
8. Minimum values presented with an asterisk (*) indicate minimum value when present. Mean value includes all subplots.
9. The designation of “NA” indicates data were not available.
10. Tables of species codes and metric conversions can be found in Appendix I and III.

Western Juniper: Phase 1

Trees: 0% Shrubs: 34% Perennial Grass: 34% Total Grass: 38% Bare Ground: 17%

06/24/07

Trees: 3% Shrubs: 23% Perennial Grass: 35% Total Grass: 35% Bare Ground: 27%

06/06/06

Site Locations: Bridge Creek, Blue Mountain, Castlehead, Devine Ridge, Walker Butte; 94 subplots

SRM Cover Types: 402 – Mountain Big Sagebrush
Fuel Model: GS1, SH1, or TU1
Elevation Range: 2838–5689 feet

Trees: 5% Shrubs: 5% Perennial Grass: 42% Total Grass: 42% Bare Ground: 38%

06/12/06

Trees: 7% Shrubs: 13% Perennial Grass: 31% Total Grass: 34% Bare Ground: 22%

05/18/07

Western Juniper: Phase 1

TREES

	JUOC			CELE3		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	<1	31	8	<1*	22	<1
Density: <1.6 ft tall (stem/ac)	23*	1817	36	23*	114	1
Density: ≥1.6 ft tall (stem/ac)	4*	115	46	8	139	1
Height (ft)	2	35	11	2	20	1
Height to live crown (ft)	<1*	7	1	<1*	8	2
Live loading (ton/ac)	0.03	14.20	3.33	NA		
Dead loading (ton/ac)	0.01*	1.95	0.30			
Available loading (ton/ac)	0.04	6.49	1.60			
Canopy bulk density (lbs/ft^3)	0.0002*	0.0063	0.0026			

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	<1*	23	1	4	58	12	23*	5110	191	0.02	0.91	0.42	0.0006	0.0274	0.0166
ARTRV	<1*	25	8	6	67	26	23*	5996	1104	0.10	4.89	1.07	0.0018	0.0462	0.0148
CHVI8	<1*	7	1	5	37	15	23*	1998	104	<0.01	0.13	0.03	<0.0001	0.0042	0.0010
PUTR2	<1*	12	2	5	95	37	23*	1272	164	<0.01	2.37	0.70	0.0001	0.0237	0.0067

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	12	53	32
Total cover: Annual grass (%)	<1*	21	3
Total cover: Forbs (%)	<1*	19	4
Grass height (in.)	4	20	9
Forb height (in.)	1*	9	4
Live herbaceous loading (lbs/ac)	54.62	720.75	240.47
Dead herbaceous loading (lbs/ac)	2.67*	809.39	158.10
Total herbaceous loading (lbs/ac)	57.29*	1530.14	398.57
Bulk density (lbs/ft^3)	0.0043	0.0577	0.0189

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.06	0.83	0.30
1.1–3.0 (100-hour)	0.05*	2.51	0.66
3.1–9.0 (1000-hour: Sound)	0.46*	9.94	1.74
3.1–9.0 (1000-hour: Rotten)	0.86*	9.01	0.33
Total	1.43*	22.29	3.03

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.1	1.3	0.6	0.01	4.20	0.43	0.0250	3.2713	0.4267
Tree duff	NA			0.1	3.9	1.4	0.09	4.67	1.20	0.0624	3.4399	0.5601
Interspace litter	5	32	18	NA			<0.01*	3.03	0.36	NA		
Bare ground	2	52	23	NA			NA			NA		

Western Juniper: Phase 2

Trees: 5% Shrubs: 22% Perennial Grass: 28% Total Grass: 28% Bare Ground: 11%

08/07/07

Trees: 10% Shrubs: 11% Perennial Grass: 21% Total Grass: 22% Bare Ground: 40%

06/23/07

Site Locations: Bridge Creek, Blue Mountain, Castlehead, Devine Ridge, Walker Butte; 86 subplots
Elevation Range: 2838–6168 feet

SRM Cover Types: 107 – Western Juniper–Big Sagebrush–Bluebunch Wheatgrass
SAF Cover Type: 238 – Western Juniper
Fuel Model: SH1 or TU1

Trees: 14% Shrubs: 24% Perennial Grass: 26% Total Grass: 26% Bare Ground: 20%

06/25/07

Trees: 21% Shrubs: 8% Perennial Grass: 15% Total Grass: 16% Bare Ground: 34%

05/21/07

Western Juniper: Phase 2

TREES

	JUOC			CELE3		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	4	55	20	<1*	18	1
Density: <1.6 ft tall (stem/ac)	23*	1453	48	23*	2180	27
Density: ≥1.6 ft tall (stem/ac)	21*	180	52	4*	45	1
Height (ft)	<1*	54	13	5	25	14
Height to live crown (ft)	<1*	13	2	1	13	6
Live loading (ton/ac)	1.40	23.50	8.66	NA		
Dead loading (ton/ac)	0.04	3.79	1.00			
Available loading (ton/ac)	0.78	11.37	4.12			
Canopy bulk density (lbs/ft³)	0.0017	0.0161	0.0062			

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft³)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	<1*	6	<1	4	23	11	182*	1771	74	<0.01	0.77	0.20	0.0002	0.0330	0.0083
ARTRV	<1*	25	7	2	63	24	159*	3452	958	0.08	2.78	0.63	0.0012	0.0344	0.0104
CHVI8	<1*	11	1	6	31	14	23*	1935	67	<0.01	0.15	0.02	<0.0001	0.0073	0.0008
PUTR2	<1*	23	4	6	109	34	23*	1385	241	0.03	2.51	0.84	0.0004	0.0244	0.0082

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	8	56	27
Total cover: Annual grass (%)	<1*	25	3
Total cover: Forbs (%)	<1	43	8
Grass height (in.)	4	19	9
Forb height (in.)	1	11	4
Live herbaceous loading (lbs/ac)	11.64	658.97	171.53
Dead herbaceous loading (lbs/ac)	2.69*	804.91	98.69
Total herbaceous loading (lbs/ac)	14.33*	1463.88	270.22
Bulk density (lbs/ft^3)	0.0027	0.0365	0.0135

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	0.83	0.32
1.1–3.0 (100-hour)	0.05*	2.46	0.79
3.1–9.0 (1000-hour: Sound)	0.61*	31.40	2.74
3.1–9.0 (1000-hour: Rotten)	0.45*	5.15	0.15
Total	1.12*	39.84	4.00

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.1	1.2	0.6	0.07	2.90	0.87	0.1373	3.1277	0.9357
Tree duff	NA			0.3	2.9	1.3	0.40	10.84	3.12	0.2497	3.7895	1.4706
Interspace litter	7	52	21	NA			<0.01*	5.62	0.66	NA		
Bare ground	4	50	23	NA			NA			NA		

Western Juniper: Phase 3

Trees: 26% Shrubs: 1% Perennial Grass: 12% Total Grass: 12% Bare Ground: 23%

06/21/06

Trees: 27% Shrubs: 4% Perennial Grass: 25% Total Grass: 25% Bare Ground: 37%

06/11/06

Site Locations: Bridge Creek, Blue Mountain, Castlehead, Devine Ridge, Walker Butte; 44 subplots
Elevation Range: 2838–6168 feet

SRM Cover Types: 107 – Western Juniper–Big Sagebrush–Bluebunch Wheatgrass
SAF Cover Types: 238 – Western Juniper
Fuel Model: TU1

Trees: 40% Shrubs: 7% Perennial Grass: 24% Total Grass: 24% Bare Ground: 23%

Trees: 51% Shrubs: 9% Perennial Grass: 1% Total Grass: 45% Bare Ground: 16%

Western Juniper: Phase 3

TREES

	JUOC			CELE3		
	Min	Max	Mean	Min	Max	Mean
Total cover (%)	10	87	35	<1*	14	1
Density: <1.6 ft tall (stem/ac)	23*	1817	62	23*	10174	233
Density: ≥1.6 ft tall (stem/ac)	45*	311	109	4*	41	3
Height (ft)	1	62	17	9	33	16
Height to live crown (ft)	<1*	23	3	1	14	7
Live loading (ton/ac)	3.36	41.92	16.18	NA		
Dead loading (ton/ac)	0.29	6.31	1.95			
Available loading (ton/ac)	1.76	20.62	7.89			
Canopy bulk density (lbs/ft^3)	0.0044	0.0287	0.0098			

SHRUBS

	Total cover (%)			Height (in.)			Density (#/acre)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
Species	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ARAR8	3*	3	<1	9	26	16	23*	1771	39	<0.01	0.02	0.01	<0.0001	0.0006	0.0002
ARTRV	<1*	10	3	1	50	23	23*	3565	375	0.01	0.64	0.16	0.0001	0.0082	0.0026
CHVI8	<1*	2	<1	2	30	13	23*	1022	57	<0.01	0.05	0.01	0.0001	0.0013	0.0004
PUTR2	<1*	11	2	6	83	35	23*	1113	158	0.02	1.60	0.56	0.0002	0.0176	0.0061

NONWOODY FUELS

	Min	Max	Mean
Total cover: Perennial grass (%)	5	45	21
Total cover: Annual grass (%)	<1*	10	2
Total cover: Forbs (%)	1	27	6
Grass height (in.)	4	17	8
Forb height (in.)	1	11	4
Live herbaceous loading (lbs/ac)	11.64	333.96	101.91
Dead herbaceous loading (lbs/ac)	2.69*	1463.88	73.92
Total herbaceous loading (lbs/ac)	14.33*	1797.84	175.83
Bulk density (lbs/ft^3)	0.0011	0.0100	0.0101

WOODY FUELS

Diameter (in.)	Loading (ton/ac)		
	Min	Max	Mean
0.26–1.0 (10-hour)	0.01	0.85	0.26
1.1–3.0 (100-hour)	0.05*	2.31	0.62
3.1–9.0 (1000-hour: Sound)	0.77*	25.81	2.75
3.1–9.0 (1000-hour: Rotten)	0.71*	90.64	2.23
Total	1.54*	119.61	5.50

LITTER and DUFF

	Total cover (%)			Depth (in.)			Total loading (ton/ac)			Bulk density (lbs/ft^3)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Tree litter	NA			0.2	1.2	0.6	0.07	5.74	1.73	0.0312	7.0233	1.7761
Tree duff	NA			0.1	2.3	1.1	0.24	13.86	4.72	0.2185	7.2481	2.3307
Interspace litter	11	56	27	NA			0.01	14.09	1.05	NA		
Bare ground	8	48	23	NA			NA			NA		

Appendix I: Species Index

Stratum	Code[1]	Scientific Name	Common Name
Trees	CELE3	*Cercocarpus ledifolius*	curl-leaf mountain mahogany
	JUOC	*Juniperus occidentalis*	western juniper
	JUOS	*Juniperus osteosperma*	little Utah juniper
	PIED	*Pinus edulis*	twoneedle pinyon pine
	PIMO	*Pinus monophylla*	singleleaf pinyon pine
Shrubs	ARAR8	*Artemisia arbuscula*	little sagebrush
	ARNO4	*Artemisia nova*	black sagebrush
	ARTRV	*Artemisia tridentata (vaseyana)*	mountain big sagebrush
	ARTRW8	*Artemisia tridentata (wyomingensis)*	Wyoming big sagebrush
	CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush
	PUTR2	*Purshia tridentata*	antelope bitterbrush

[1]USDA NRCS 2008

Stratum	Code[1]	Scientific Name	Common Name
Graminoids	ACHY	*Achnatherum hymenoides*	Indian ricegrass
	ACNE10	*Achnatherum nevadense*	Nevada needlegrass
	ACTH7	*Achnatherum thurberianum*	Thurber's needlegrass
	BRAR5	*Bromus arvensis*	field brome
	BRTE	*Bromus tectorum*	cheatgrass
	ELEL5	*Elymus elymoides*	squirreltail
	FEID	*Festuca idahoensis*	Idaho fescue
	HECO26	*Hesperostipa comata*	needle and thread
	LECI4	*Leymus cinereus*	basin wild rye grass
	PASM	*Pasceopyrum smithii*	western wheatgrass
	PLJA	*Pleuraphis jamesii*	James' galleta
	POCU3	*Poa cusickii*	Cusick's bluegrass
	POSE	*Poa secunda*	Sandberg bluegrass
	PSSPS	*Pseudoroegneria spicata spicata*	bluebunch wheatgrass

[1]USDA NRCS 2008

Appendix II: Glossary of Terms

Available fuel loading: Fuel that could be readily consumed at any given time. Highly dependent of fuel moisture, particle size and arrangement (Miller 2001).

Biomass: All vegetation on the site (Miller 2001).

Bulk density: Weight of biomass per unit volume; loading/fuel depth (Brown 1982).

Common species: Species that have the highest abundance on the site.

Community: An assemblage of plants, animals, bacteria and fungi that live in an environment, interact with one another, forming a distinctive living system within its own composition, structure, environmental relations, development and function (Whittaker 1975). It is the biotic component of the ecosystem and has no implicit definition of spatial extent or boundaries (Kimmins 1987).

Dominant species: Species that exerts ecological influence over other species on the site.

Duff: The fermentation and humus layers of the forest floor. Needles, leaves, and other castoff vegetation are no longer distinguishable due to decomposition (Brown 1974).

Ecosystem: The community and non-living environment functioning together as an ecological system (Odum 1971). No implicit definition of spatial extent or boundaries (Kimmins 1987).

Fire behavior fuel model: General description of fuel properties and fuel characteristics, including loading and surface-to-area volume, created for the purpose of fire behavior prediction (Anderson 1982).

Fire behavior model: A computer model that uses a set of physically based mathematical equations to predict certain aspects of fire behavior. Inputs include fuel characteristics and environmental conditions for a particular site (Rothermel 1972).

Fire regime: A general description of the role fire plays in an ecosystem. It can be described by characteristics of the disturbance (type, frequency, predictability, extent, magnitude, synergism or timing), a summary of the ecological effects on the dominant or potential vegetation of the ecosystems, or the fire severity on dominant vegetation (Agee 1993).

Fire return interval: The number of years between two successive fire events at a specific site or an area of a specified size (Agee 1993).

Fuel: Live and dead biomass that contribute to wildland fire (Davis 1959). Often defined by loading depth, height and bulk density.

Fuelbed: Measured or averaged physical characteristics of reactively uniform unit on the landscape that represents a distinct fire environment (Riccardi et al. 2001).

Fuelbed depth: Depth of surface fuel available to the flaming front (Miller 2001).

Fuel continuity: Relates to the proximity of individual fuel particles as well as different fuel strata. It affects fire spread, ignition rates and area and how much consumption takes place (Miller 2001).

Fuel loading: Weight of fuel per unit area (Brown 1982).

Fuel strata: A horizontal layer of fuel having approximately the same composition throughout; parallel layers arranged one on top of another. Identified in this Guide as trees, shrubs, nonwoody fuel, woody fuels, litter and duff (Ottmar et al. 2007, Sandberg et al. 2001).

Litter: The surface layer of the site consisting of freshly fallen leaves, needles, twigs, bark and fruits (Brown 1974).

Time lag: The length of time it takes a fuel particle to reach 63 percent equilibrium moisture content with the environment at standard conditions of 80ºF and 20 percent relative humidity (Schroeder and Buck 1970).

1-hour fuel: Fuel particles with 0.00–0.24 in. (0–0.6 cm) diameter; fuel size class distinction (Brown 1974). One-hour refers to the timelag.

10-hour fuel: Fuel particles with 0.25–0.99 in. (0.6–2.5 cm) diameter; fuel size class distinction (Brown 1974). Ten-hour refers to the timelag.

100-hour fuel: Fuel particles with 1.00–2.99 in. (2.5–7.6 cm) diameter; fuel size class distinction (Brown 1974). Hundred-hour refers to the timelag.

1000-hour fuel: Fuel particles with greater than 3.00 in. (7.6 cm) diameter; fuel size class distinction (Brown 1974). Thousand-hour refers to the timelag.

Appendix III: Conversion Table

Reported Unit	Conversions
1 ac	0.4050 ha; 4046.8560 m^2
1 in.	2.5400 cm
1 ft	0.3048 m
1 lb	0.0005 ton; 0.4520 kg
1 lb/ac	0.0005 ton/ac; 0.0001 kg/m^2; 1.1200 kg/ha
1 ton	907.2000 kg
1 ton/ac	0.2242 kg/m^2; 2241.7023 kg/ha
1 lb/ft^3	16.0000 kg/m^3

Appendix IV: Tree Loadings by Size Class

Size class loadings were calculated using allometric equations developed by Sabin (2008) and Tausch (2008). This information will be useful as more accurate information becomes available about the percentage of various size classes that are available to burn under certain environmental conditions. The authors recommend users make their own assumptions about available canopy fuels based on their experience or current literature.

Guide	Phase	Species	Foliar loading (ton/ac)			1-hour loading (ton/ac)			10-hour loading (ton/ac)			100-hour loading (ton/ac)			1000-hour loading (ton/ac)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Pinyon-Juniper	1	JUOS	0.01	3.23	0.65	<0.01	1.34	0.20	<0.01	1.78	0.31	<0.01	2.88	0.43	0.01	6.90	0.78
		PIMO	<0.01	1.05	0.22	<0.01	0.89	0.16	<0.01	0.01	0.19	<0.01	1.33	0.24	<0.01	2.38	0.37
	2	JUOS	0.01	4.85	1.43	<0.01	1.71	0.48	<0.01	2.45	0.72	<0.01	3.34	1.04	0.02	8.29	2.12
		PIMO	<0.01	2.65	0.83	<0.01	2.16	0.61	<0.01	2.52	0.72	<0.01	3.13	0.94	<0.01	0.62	0.14
	3	JUOS	0.21	4.15	2.92	0.07	3.20	1.06	0.12	4.18	1.53	0.17	6.96	2.29	0.32	17.42	4.87
		PIMO	0.01	3.58	1.85	0.01	3.15	1.44	0.02	3.74	1.70	0.01	4.23	2.13	<0.01	7.74	3.40
Utah Juniper	1	JUOS	0.04	2.61	0.76	0.01	1.12	0.27	0.02	1.47	0.39	0.02	2.27	0.55	0.02	5.35	1.06
		PIED	<0.01	0.55	0.19	0.01	0.38	0.13	0.01	0.46	0.16	<0.01	0.60	0.20	0.01	0.90	0.28
	2	JUOS	0.04	4.35	1.48	0.01	1.77	0.52	0.02	2.42	0.76	0.02	3.62	1.08	0.02	8.07	2.12
		PIED	0.01	1.13	0.42	<0.01	0.80	0.29	<0.01	0.96	0.35	<0.01	1.21	0.45	<0.01	1.80	0.62
	3	JUOS	0.83	6.50	2.50	0.26	2.16	0.85	0.41	3.19	1.26	0.53	3.84	1.73	0.89	8.07	3.23
		PIED	0.02	2.51	0.84	0.01	1.70	0.57	0.02	2.05	0.69	0.01	2.62	0.88	0.01	3.76	1.25
Western Juniper	1	JUOC	<0.01	2.67	0.14	0.04	5.13	1.28	0.02	2.71	0.66	<0.01	3.71	0.69	0.02	4.60	1.04
	2	JUOC	0.01	4.32	0.35	0.62	9.00	3.27	0.31	4.75	1.70	0.21	6.37	1.99	0.30	7.18	2.67
	3	JUOC	<0.01	4.74	0.33	1.40	16.33	6.10	0.71	8.58	3.18	0.67	10.17	3.70	0.97	13.15	5.14

Appendix V: Shrub Loadings by Size Class

Size class loadings were calculated from site- and species-specific linear regressions developed from harvest sampling (Pechanec and Pickford 1937, Riser 1984). Various combinations of shrub height, longest diameter, perpendicular diameter and volume were used as predictor variables in the regressions. One-hour loading includes foliage and 1-hour fuels from the shrub canopy. The available loading assumes 100% of the 1-hour and 50% of the 10-hour fuels will consume in the flaming front (Wright 2008).

Guide	Group	Species	1-hour loading (ton/ac)			10-hour loading (ton/ac)			Available loading (ton/ac)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Sagebrush Steppe	1	ARTRW8	0.15	2.19	1.27	0.04	2.47	0.80	0.05	6.09	1.04
		CHVI8	<0.01	0.19	0.05	<0.01	0.05	0.01	<0.01	0.21	0.01
	2	ARTRW8	<0.01	2.40	0.71	<0.01	2.89	0.78	0.12	3.85	0.57
		CHVI8	<0.01	0.30	0.04	<0.01	0.10	0.01	<0.01	0.35	0.01
	3	ARTRW8	0.39	13.27	4.57	0.04	3.71	0.73	0.46	12.80	4.57
		CHVI8	<0.01	0.97	0.31	<0.01	0.39	0.13	0.01	1.17	0.38
	4	ARTRW8	0.04	2.17	0.59	0.04	1.92	0.53	0.06	3.13	0.67
		CHVI8	<0.01	0.04	0.01	<0.01	0.01	<0.01	<0.01	0.04	<0.01

Guide	Phase	Species	1-hour loading (ton/ac)			10-hour loading (ton/ac)			Available loading (ton/ac)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Pinyon-Juniper	1	ARAR8	NA						NA		
		ARNO4	<0.01	1.38	0.58	<0.01	1.00	0.42	<0.01	1.88	0.71
		ARTRV	0.01	0.97	0.29	<0.01	0.68	0.26	<0.01	1.31	0.38
		ARTRW8	0.02	1.35	0.50	0.01	1.82	0.34	0.06	1.82	0.24
		CHVI8	<0.01	0.41	0.09	<0.01	0.07	0.01	<0.01	0.38	0.08
		PUTR2	0.01	0.77	0.22	<0.01	0.88	0.19	<0.01	1.21	0.22
	2	ARAR8	0.01	0.21	0.07	<0.01	0.15	0.05	0.02	0.28	0.10
		ARNO4	0.08	1.15	0.41	0.03	0.89	0.28	<0.01	1.59	0.55
		ARTRV	<0.01	0.42	0.08	<0.01	0.24	0.08	<0.01	0.53	0.09
		ARTRW8	<0.01	1.19	0.40	<0.01	0.55	0.16	0.01	1.47	0.42
		CHVI8	<0.01	0.17	0.03	<0.01	0.02	0.01	<0.01	0.18	0.03
		PUTR2	0.03	0.67	0.19	0.01	0.83	0.19	0.03	1.08	0.29
	3	ARAR8	<0.01	0.06	0.06	0.02	0.04	0.03	0.03	0.08	0.05
		ARNO4	0.01	0.19	0.07	<0.01	0.60	0.13	<0.01	0.24	0.09
		ARTRV	<0.01	0.23	0.05	<0.01	0.16	0.04	<0.01	0.31	0.07
		ARTRW8	0.01	0.23	0.09	<0.01	0.09	0.03	<0.01	0.27	0.10
		CHVI8	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
		PUTR2	0.01	0.29	0.09	<0.01	0.30	0.08	<0.01	0.44	0.14

Guide	Phase	Species	1-hour loading (ton/ac)			10-hour loading (ton/ac)			Available loading (ton/ac)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Utah Juniper	1	ARTRV	0.04	2.10	0.86	0.03	2.50	0.95	0.05	3.35	1.34
		ARTRW8	0.11	1.81	0.79	0.09	2.04	0.85	0.12	2.82	1.22
		CHVI8	0.02	0.56	0.22	NA			0.01	0.50	0.15
		PUTR2	0.30	1.87	0.92	0.32	2.11	1.13	0.37	2.92	1.49
	2	ARTRV	0.01	1.81	0.55	0.01	2.02	0.62	0.02	2.82	0.86
		ARTRW8	<0.01	1.56	0.49	< 0.01	2.08	0.53	0.04	2.60	0.74
		CHVI8	<0.01	0.44	0.10	NA			<0.01	0.44	0.10
		PUTR2	0.05	1.25	0.46	0.05	1.67	0.61	<0.01	2.08	0.72
	3	ARTRV	0.01	0.44	0.20	0.01	0.52	0.21	0.01	0.70	0.30
		ARTRW8	<0.01	0.73	0.19	0.01	1.08	0.24	0.01	1.27	0.32
		CHVI8	<0.01	0.03	0.01	NA			<0.01	0.03	0.01
		PUTR2	0.01	0.58	0.19	0.01	0.80	0.24	0.01	0.96	0.30

Guide	Phase	Species	1-hour loading (ton/ac)			10-hour loading (ton/ac)			Available loading (ton/ac)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Western Juniper	1	ARAR8	0.01	0.60	0.28	0.01	0.34	0.17	0.01	0.77	0.08
		ARTRV	0.05	2.36	0.53	0.06	1.84	0.45	0.08	3.28	0.76
		CHVI8	<0.01	0.13	0.03	NA			<0.01	0.11	0.03
		PUTR2	<0.01	0.99	0.28	<0.01	2.06	0.45	<0.01	2.02	0.47
	2	ARAR8	<0.01	0.49	0.13	<0.01	0.33	0.08	<0.01	0.66	0.05
		ARTRV	0.03	1.33	0.32	0.03	1.04	0.29	0.05	1.85	0.46
		CHVI8	<0.01	0.15	0.02	NA			<0.01	0.15	0.01
		PUTR2	0.02	1.03	0.35	<0.01	2.18	0.53	0.02	2.13	0.34
	3	ARAR8	<0.01	0.08	0.02	<0.01	0.03	0.01	<0.01	0.09	0.02
		ARTRV	<0.01	0.26	0.07	<0.01	0.28	0.07	<0.01	0.40	0.11
		CHVI8	<0.01	0.05	0.01	NA			<0.01	0.04	0.01
		PUTR2	0.01	0.71	0.25	0.01	1.07	0.35	0.01	1.25	0.23

Appendix VI: Shrub Sample Ranges

Sagebrush Steppe: Sample ranges used to predict shrub loadings. R^2 values are the lowest calculated values from all developed regressions.

	Height (in.)	Longest Diameter (in.)	Perpendicular Diameter (in.)	Volume (in^3)	R^2
ARTRW8	8–57	7–75	3–57	61–125138	0.80
CHVI8	10–28	9–48	5–42	332–18686	0.67

Pinyon-Juniper: Sample ranges used to predict shrub loadings. R^2 values are the lowest calculated values from all developed regressions.

	Height (in.)	Longest Diameter (in.)	Perpendicular Diameter (in.)	Volume (in^3)	R^2
ARAR8	4–19	9–34	7–31	164–9731	0.90
ARNO4	3–24	2–55	2–35	5–19593	0.78
ARTRV	6–39	6–49	4–17	82–50995	0.93
ARTRW8	2–55	3–63	2–51	9–75889	0.79
CHVI8	4–51	5–73	4–31	62–61476	0.81
PUTR2	5–75	4–146	4–91	38–516631	0.90

Utah Juniper: Sample ranges used to predict shrub loadings. R^2 values are the lowest calculated values from all developed regressions

	Height (in.)	Longest Diameter (in.)	Perpendicular Diameter (in.)	Volume (in^3)	R^2
ARTRV	6–64	8–78	8–45	215–96153	0.84
ARTRW8	6–52	6–72	4–61	111–88538	0.86
CHVI8	7–24	7–31	7–22	229–6460	0.74
PUTR2	6–79	13–149	7–138	305–762917	0.97

Western Juniper: Sample ranges used to predict shrub loadings. R^2 values are the lowest calculated values from all developed regressions.

	Height (in.)	Longest Diameter (in.)	Perpendicular Diameter (in.)	Volume (in^3)	R^2
ARAR8	6–17	7–32	2–24	66–5870	0.84
ARTRV	8–51	7–66	6–62	194–104745	0.68
CHVI8	7–29	4–38	2–33	43–14747	0.62
PUTR2	7–89	10–119	5–101	268–556134	0.94